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PE900161

OIL and GAS DIVISION  
WELL COMPLETION REPORT  
Bridgewater Bay No. 1  
0 7 JUN 1984



PHILLIPS AUSTRALIAN OIL COMPANY  
PERTH, WESTERN AUSTRALIA

OIL and GAS DIVISION

WELL COMPLETION REPORT

Bridgewater Bay No. 1

0 7 JUN 1984

Phillips Australian Oil Company

June, 1984

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\*Interpretive and Confidential Data

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\*Interpretative and Confidential data

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### Addenda

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- 3 Well Velocity Survey
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\*Interpretative and Confidential Data

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BASIC HYDROCARBON SOURCE ROCK POTENTIAL

ANALYSIS OF BRIDGEWATER BAY No. 1

SIDEWALL CORE SAMPLES\*

# PETROLEUM GEOCHEMISTRY

HYDROCARBON SOURCE ROCK

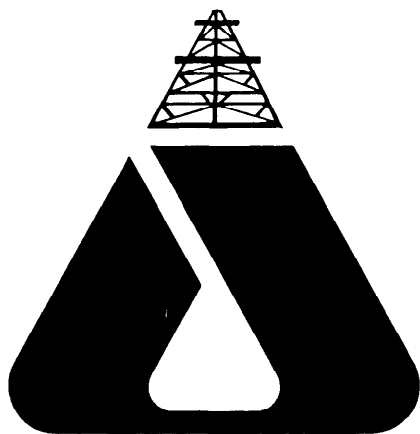
EVALUATION STUDY

BRIDGEWATER BAY NO. 1

Prepared for

PHILLIPS AUSTRALIAN OIL COMPANY

MARCH, 1984.



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# HYDROCARBON SOURCE ROCK

## EVALUATION STUDY

### BRIDGEWATER BAY NO. 1

#### SUMMARY

Organic geochemical analyses performed on well cutting samples between 1130m to 4200m in the Phillips Australian Oil Company, Bridgewater Bay No. 1 well drilled in Vic-P-14 offshore Victoria, Australia in the Otway Basin have indicated:

- ° The rocks from 2800m to 3200m are marginally mature and considered to be in the initial stages of petroleum generation. Reliable maturity data is unavailable for the remaining intervals penetrated by this well, however, we suspect that the maturity at the bottom of the well does not exceed oil generating maturation levels.
- ° The rocks between 2700m to 3550m have an overall poor oil and gas source character with marginal to moderate hydrocarbon source potential at 2700m, 2945m and 3050m.
- ° The rocks below 3550m are contaminated with an oil base mud additive, which has affected the total organic carbon and pyrolysis results. The C<sub>1</sub>-C<sub>7</sub> light hydrocarbon results appear to be unaffected, however the values are low and indicate these rocks have poor oil and gas generating capabilities.



PAUL TYBOR



## INTRODUCTION

Organic geochemical analyses have been performed on well cutting samples between 1130m to 4200m in the Phillips Australian Oil Company's Bridgewater Bay No. 1 well, drilled in Vic-P-14 offshore Victoria, Australia in the Otway Basin (38° 32'26"S; 141° 21'48"E).

The purpose of this study has been to evaluate the hydrocarbon source quality (oil vs gas), richness and state of thermal maturity (pre oil, oil-generative, post oil-generative) of the rocks analysed from this well.

### Analytical

The samples from this well were assigned the Analabs Job Number 31840. A total of two hundred and seventy-seven (277) wet canned well cuttings were submitted to C<sub>1</sub>-C<sub>7</sub> light hydrocarbon head space gas chromatography. Another thirty-one (31) samples, which were picked and high graded by Phillips personnel, were analysed by % total organic carbon and Rock-Eval pyrolysis analysis. Four (4) samples were chosen for vitrinite reflectance, and these were sent to David Marchioni and Associates for assessment.

The results of these analyses are presented in the following:

<u>Type of Analysis</u>	<u>Figure</u>	<u>Table</u>
C <sub>1</sub> -C <sub>7</sub> light hydrocarbon head space gas chromatography	1	1
% total organic carbon determination	2	2
Pyrolysis analysis	2	2
Vitrinite reflectance and coal maceral description	1,2,3	

A description of the various analyses performed on these samples is provided in the Theory and Methods section, located at the rear of this report.

#### General Information

Copies of this report have been sent to Mr. Dave Murray of the Phillips Australian Oil Company in Perth, Western Australia. Any questions regarding the data or interpretations given herein may be directed to either Mr. Paul Tybor or Dr. Garry Woodhouse of Analabs, Perth, Western Australia.

All of the contents contained in this study are considered proprietary to the Phillips Australian Oil Company, and are treated as highly confidential material by all Analabs personnel.

## RESULTS AND INTERPRETATIONS

### A. Thermal Maturity of Sediments

The maturity data available for samples from this well are limited due to apparent poor quality organic matter, within the sediments, and contamination added to the drilling mud.

Vitrinite reflectance was performed on four samples at 2800m, 3200m, 3600m and 4200m, with only the two samples at 2800m and 3200m containing measurable vitrinite. Both samples gave marginally mature reflectances (0.55 % Ro and 0.53 % Ro; Figures 1, 2 and 3), which places these rocks in the initial stages of petroleum generation.

Tmax pyrolysis temperatures were obtained from thirty-one (31) picked cuttings samples. The temperatures in the contaminated zone below 3600m are interpreted to be unreliable due to this contamination. In the overlying uncontaminated section the temperatures vary greatly, without any recognisable maturity trend present. The pyrograms illustrate very erratic S<sub>2</sub> peaks, the peak at which Tmax is recorded, which we interpret to be due to the poor quality organic matter present in these samples (ie. reworked, inertinite).

In summary, the sedimentary section penetrated by this well, has probably experienced a low degree of thermal maturation, based on the marginally mature % Ro values obtained at 2800m and 3200m. Below these depths we can only speculate on the maturity of the rocks, however, we feel that the sediments do not obtain levels much higher than marginally/moderately mature, and would be within the top to middle portions of the oil window.

## B. Hydrocarbon Source Characterisation

Due to the drilling mud contamination present in the samples below 3600m, it is difficult to determine the hydrocarbon source rock character of these sediments. However, the C<sub>1</sub>-C<sub>7</sub> light hydrocarbon headspace gas chromatography data does not appear to have affected, as has the % T.O.C. and pyrolysis data. This gas data is low (Figure 1; Table 1), and consequently we interpret these sediments have poor hydrocarbon source rock characteristics.

The samples in the uncontaminated section contain good amounts of organic matter (>1.0% T.O.C.; Figures 1 and 2; Table 2), but the quality appears to be low due to the overall low hydrogen index values observed (Figure 2; Table 2). As a result, the potential yields are low (S<sub>1</sub>+S<sub>2</sub>; Figure 2; Table 2), which gives these sediments an overall poor hydrocarbon source character. The samples at 2700m, 2945m and 3050m, have moderate hydrogen index values, with marginal to moderate potential yields.

In summation, the sediments between 2700m to 3600m have overall poor oil and gas source potential, with thin zones at 2700m, 2945m and 3050m having marginal to moderate oil and gas potential at higher levels of thermal maturity.

PE902247

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The enclosure PE902247 has the following characteristics:

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CONTAINER_BARCODE	= PE900161
NAME	= Bridgewater Bay 1 Figure 1 (Appendix 7) ANA-LOG Hydrocarbon Source Rock Evaluation C1-C7 Light Hydrocarbon
BASIN	= OTWAY
TYPE	= WELL
SUBTYPE	= LOG
DESCRIPTION	= Bridgewater Bay 1 Figure 1 (Appendix 7) ANA-LOG Hydrocarbon Source Rock Evaluation C1-C7 Light Hydrocarbon
W_NO	= W831
WELL_NAME	= BRIDGEWATER BAY-1
CLIENT_OP_CO	= PHILLIPS AUSTRALIAN OIL COMPANY

FIGURE 1  
FEBRUARY 1984



# ANA-LOG

## HYDROCARBON SOURCE ROCK EVALUATION

PHILLIPS AUSTRALIAN OIL COMPANY  
BRIDGEWATER BAY #1

- LIME
- DOLOMITE
- CLAY
- SILT
- SAND
- COAL
- IGNEOUS
- META
- EVAPORITE

IN METRES  
IN FEET

**SAMPLE TYPE**

- CUTTINGS
- CONV. CORE
- SWC

**SAMPLE QUALITY**

- POOR
- FAIR
- GOOD

### C1 - C7 LIGHT HYDROCARBON

C1 - DRY GAS  
 C2 - C4 - WET GAS + % GAS WETNESS  
 C1 - C4 - TOTAL GAS \* C2 - C4  
 C5 - C7 - CONDENSATE C1 - C4 x 100  
 1C4 - ISOBUTANE  
 nC4 - NORMAL BUTANE

PRE OIL WINDOW  
 OIL WINDOW  
 WET GAS/COND  
 THERMAL C1

**INDIGENOUS KEROGEN**

- ALGINITE
- EXINITE
- VITRINITE
- INERTINITE

LITHOLOGY (Percent)  
20 40 60 80

DEPTH

ORGANIC CARBON (Percent of Rock)  
.25 .5 1 2 4

C1 - C4 ppm  
100 1000 10000

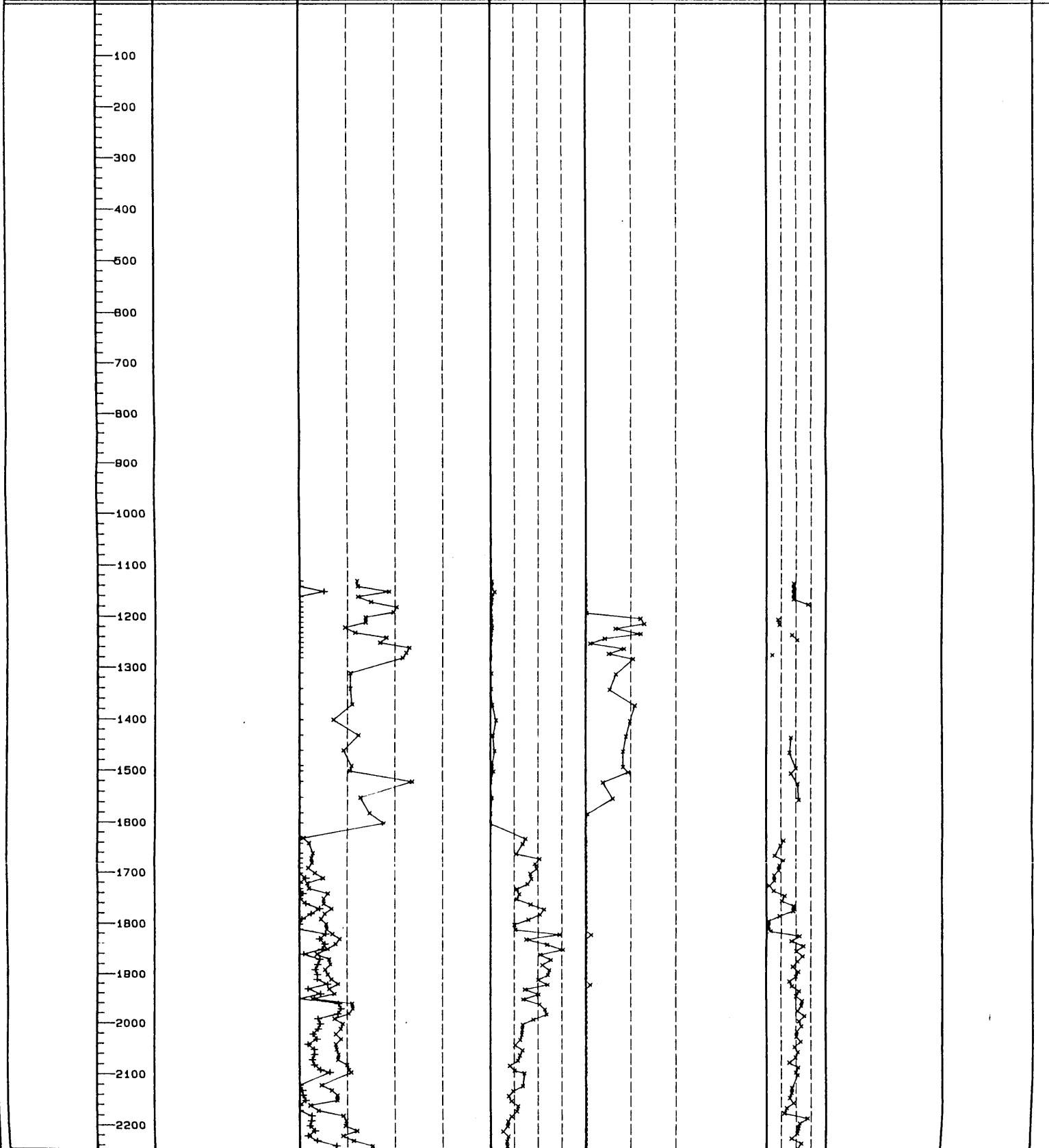
% GAS WETNESS  
25 50 75

C5 - C7 ppm  
100 1000 10000

1C4/nC4  
1 2 3

▲ VITRINITE REFLECTANCE  
.8 1.2 1.8

INDIGENOUS KEROGEN  
25 50 75



PE902246

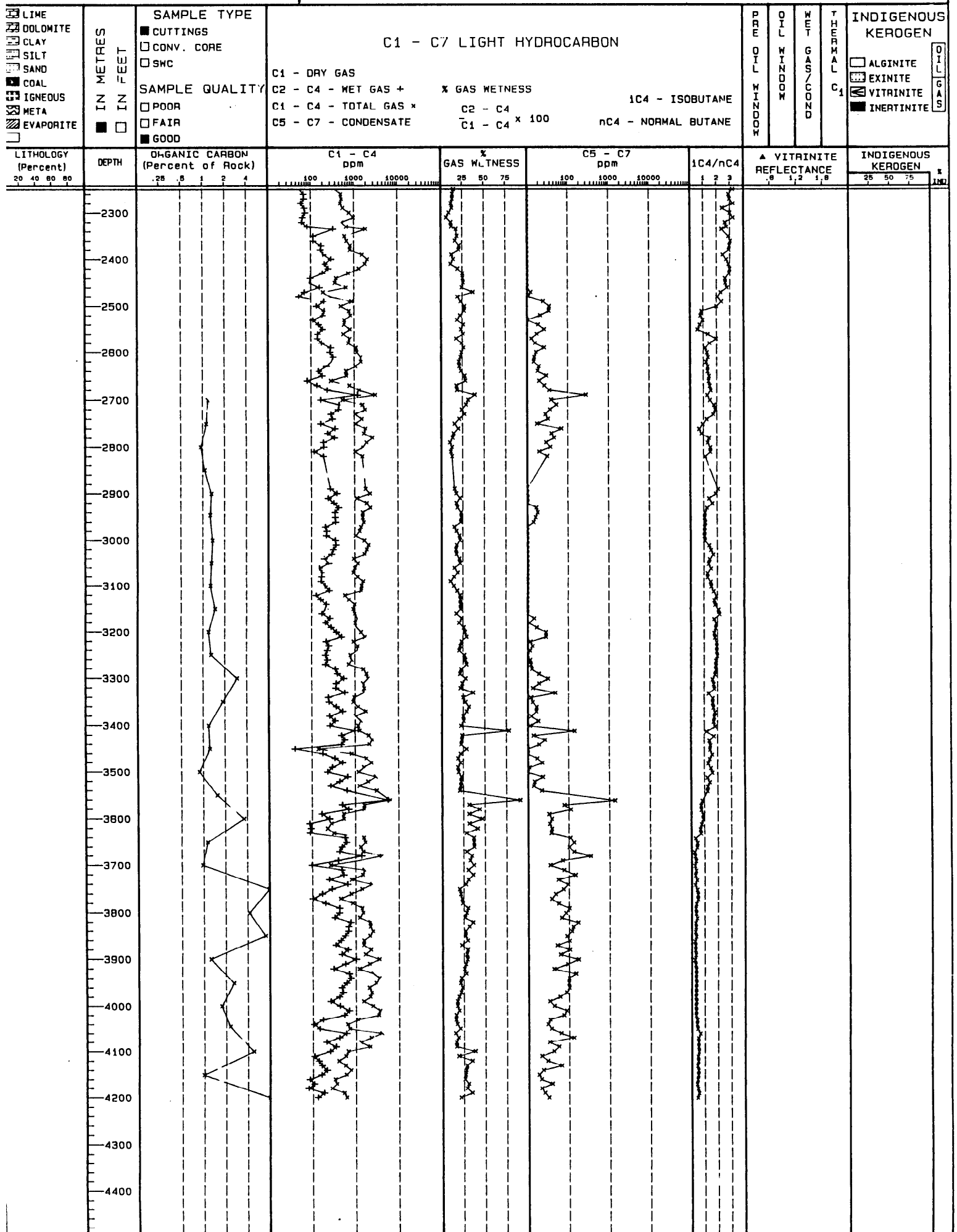
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BASIN	= OTWAY
TYPE	= WELL
SUBTYPE	= LOG
DESCRIPTION	= Bridgewater Bay 1 Figure 1 (Appendix 7) ANA-LOG Hydrocarbon Source Rock Evaluation C1-C7 Light Hydrocarbon
W_NO	= W831
WELL_NAME	= BRIDGEWATER BAY-1
CLIENT_OP_CO	= PHILLIPS AUSTRALIAN OIL COMPANY

# ANA-LOG

## HYDROCARBON SOURCE ROCK EVALUATION





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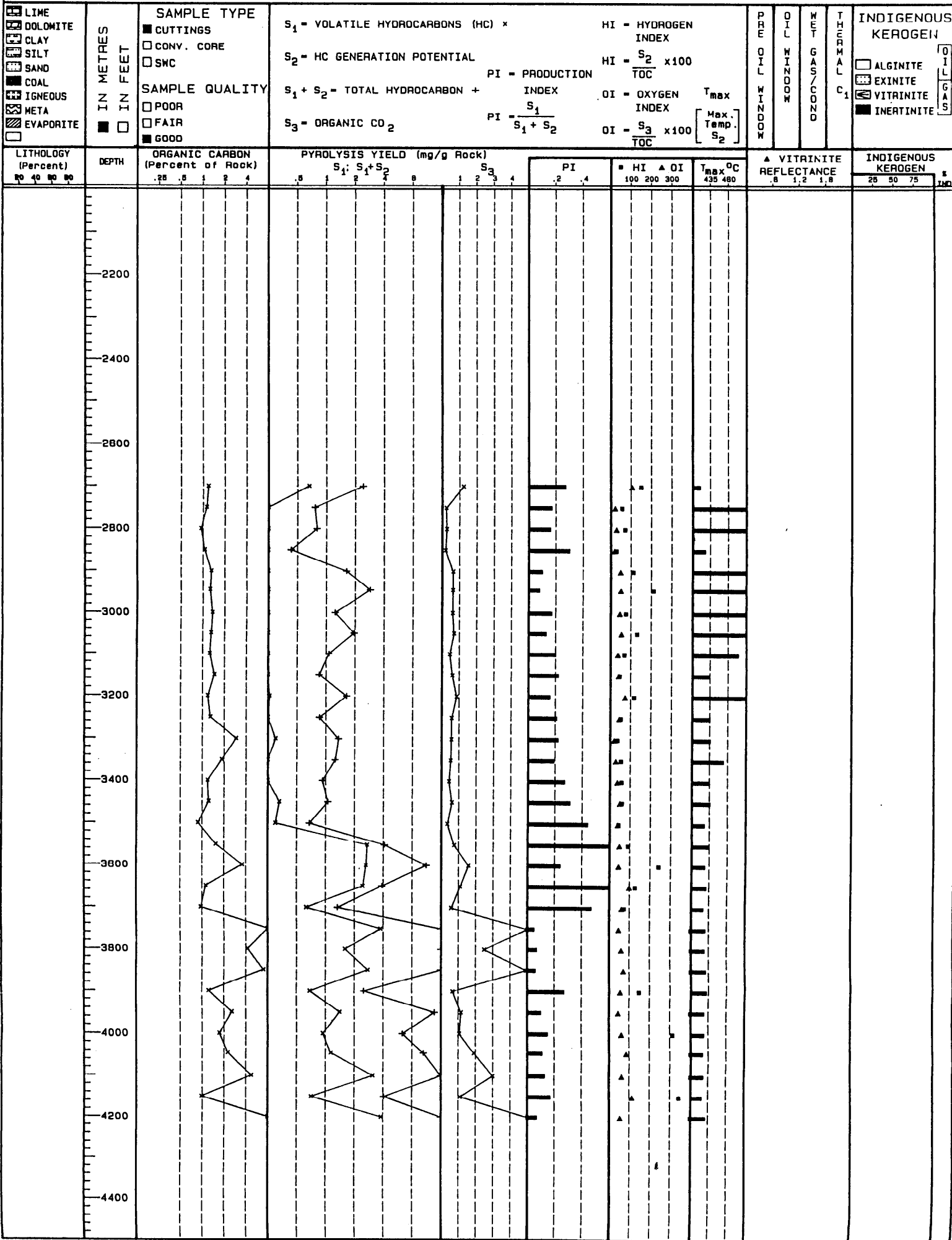
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BASIN	= OTWAY
TYPE	= WELL
SUBTYPE	= LOG
DESCRIPTION	= Bridgewater Bay 1 Figure 2 (Appendix 7) ANA-LOG Hydrocarbon Source Rock Evaluation S1, S2, S3, HI, OI & PI
W_NO	= W831
WELL_NAME	= BRIDGEWATER BAY-1
CLIENT_OP_CO	= PHILLIPS AUSTRALIAN OIL COMPANY



# ANA-LOG

## HYDROCARBON SOURCE ROCK EVALUATION



PE902244

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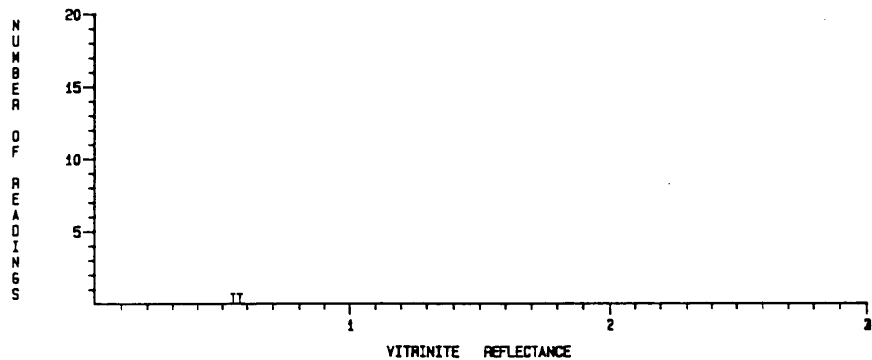
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CONTAINER_BARCODE	= PE900161
NAME	= Bridgewater Bay 1 Figure 3 (Appendix 7) Vitrinite Reflectance & Coal Maceral Identification
BASIN	= OTWAY
TYPE	= WELL
SUBTYPE	= DIAGRAM
DESCRIPTION	= Bridgewater Bay 1 Figure 3 (Appendix 7) Vitrinite Reflectance & Coal Maceral identification
W_NO	= W831
WELL_NAME	= BRIDGEWATER BAY-1
CLIENT_OP_CO	= PHILLIPS AUSTRALIAN OIL COMPANY

FIGURE : 3  
VITRINITE REFLECTANCE AND COAL MACERAL IDENTIFICATION

CLIENT NAME : PHILLIPS AUSTRALIA DATE : MARCH 1984  
DEPTH OR SAMPLE No : 2800 Meters  
(Total No. of Readings - 2) 0.54 0.57

WELL NAME : BRIDGEWATER BAY #1  
SAMPLE TYPE : CUTTINGS

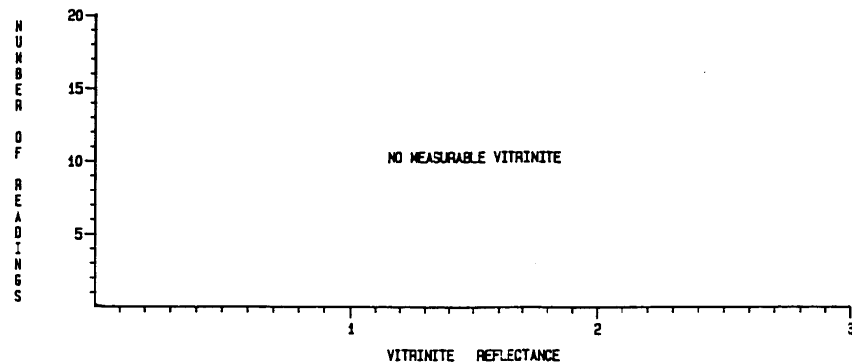
VITRINITE REFLECTANCE							MACERAL IDENTIFICATION				
POPULATION Number	%	No. of Readings	Mean Ro (X)	Min. Ro (X)	Max. Ro (X)	STD. Dev. (X)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100	2	0.56	0.54	0.57	0.02	INDIGENOUS (I)	0.00	80.00	25.00	15.00



CLIENT NAME : PHILLIPS AUSTRALIA DATE : MARCH 1984  
DEPTH OR SAMPLE No : 3600 Meters  
(Total No. of Readings - 0)

WELL NAME : BRIDGEWATER BAY #1  
SAMPLE TYPE : CUTTINGS

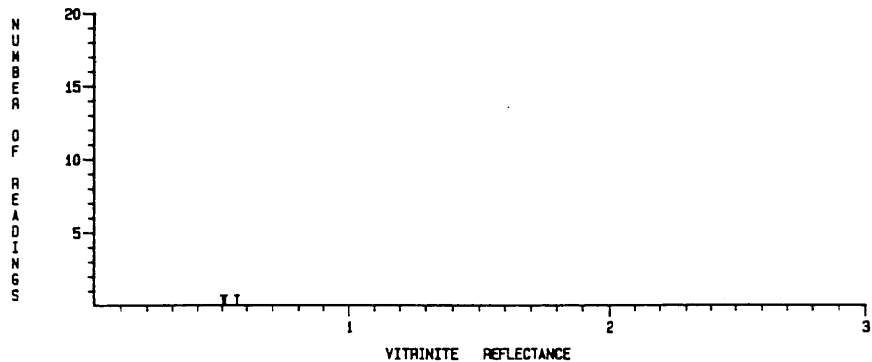
VITRINITE REFLECTANCE							MACERAL IDENTIFICATION				
POPULATION Number	%	No. of Readings	Mean Ro (X)	Min. Ro (X)	Max. Ro (X)	STD. Dev. (X)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
NO MEASURABLE VITRINITE											



CLIENT NAME : PHILLIPS AUSTRALIA DATE : MARCH 1984  
DEPTH OR SAMPLE No : 3200 Meters  
(Total No. of Readings - 3) 0.50 0.51 0.56

WELL NAME : BRIDGEWATER BAY #1  
SAMPLE TYPE : CUTTINGS

VITRINITE REFLECTANCE							MACERAL IDENTIFICATION				
POPULATION Number	%	No. of Readings	Mean Ro (X)	Min. Ro (X)	Max. Ro (X)	STD. Dev. (X)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100	3	0.52	0.50	0.56	0.03	INDIGENOUS (I)	0.00	11.00	4.00	85.00



CLIENT NAME : PHILLIPS AUSTRALIA DATE : MARCH 1984  
DEPTH OR SAMPLE No : 4200 Meters  
(Total No. of Readings - 0)

WELL NAME : BRIDGEWATER BAY #1  
SAMPLE TYPE : CUTTINGS

VITRINITE REFLECTANCE							MACERAL IDENTIFICATION				
POPULATION Number	%	No. of Readings	Mean Ro (X)	Min. Ro (X)	Max. Ro (X)	STD. Dev. (X)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
NO MEASURABLE VITRINITE											

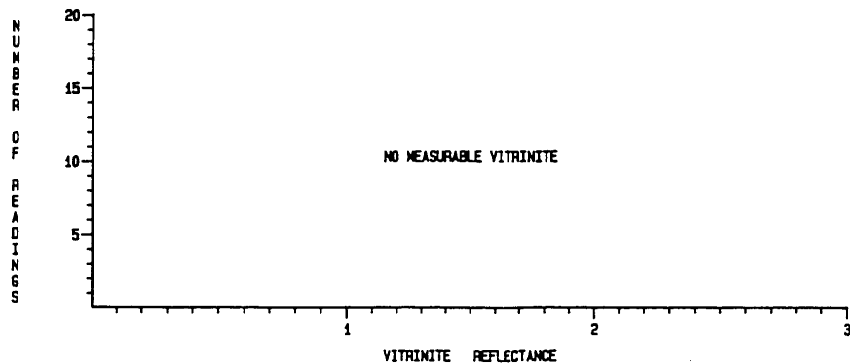


TABLE 1

WELLNAME = BRIDGEWATER BAY #1

DATE OF JOB = JANUARY 1984

## HEADSPACE ANALYSIS DATA

DEPTH (m)	METHANE	ETHANE	PROPANE	ISOBUTANE	BUTANE	C1-C4	C2-C4	ZWETNESS	C5-C7	i-C4/n-C4
1130.0	157.7	0.9	0.5	0.5	0.3	159.8	2.1	1.3	<0.1	1.83
1140.0	162.0	0.5	0.2	0.4	0.2	163.4	1.4	.9	<0.1	1.83
1150.0	721.1	14.3	8.8	6.1	3.3	753.6	32.5	4.3	<0.1	1.83
1160.0	164.3	1.4	0.7	0.4	0.2	167.0	2.7	1.6	<0.1	1.83
1170.0	311.2	1.8	0.9	0.4	0.1	314.4	3.2	1.0	<0.1	2.80
1180.0	1072.3	1.5	0.7	0.3	<0.1	1074.8	2.6	.2	<0.1	bd1
1190.0	934.6	0.2	0.3	0.1	<0.1	935.2	0.7	.1	10.5	bd1
1200.0	237.8	0.9	0.5	0.2	0.2	239.7	1.8	.8	164.7	0.79
1210.0	240.6	1.3	0.7	0.3	0.3	243.2	2.5	1.0	199.6	0.88
1220.0	87.9	0.6	0.4	0.3	<0.1	89.3	1.5	1.7	45.7	bd1
1230.0	145.6	0.6	0.4	0.3	0.2	147.0	1.4	.9	166.4	1.73
1240.0	662.2	2.2	0.4	0.3	0.1	665.2	3.0	.4	26.5	2.09
1250.0	479.5	1.0	0.3	0.2	<0.1	481.1	1.6	.3	12.5	bd1
1260.0	2014.1	0.5	0.3	<0.1	0.2	2015.1	1.0	.0	70.8	bd1
1270.0	1723.1	0.7	0.4	0.1	0.3	1724.7	1.5	.1	32.4	0.40
1280.0	1457.5	0.5	0.4	<0.1	0.2	1458.7	1.2	.1	112.2	bd1
1310.0	115.0	1.0	0.4	<0.1	<0.1	116.4	1.4	1.2	46.9	bd1
1340.0	115.8	0.8	0.3	<0.1	<0.1	116.9	1.1	.9	34.0	bd1
1370.0	123.2	2.1	0.7	<0.1	<0.1	126.0	2.8	2.2	122.3	bd1
1400.0	47.9	2.1	0.9	<0.1	<0.1	51.0	3.1	6.0	95.7	bd1
1430.0	166.8	2.8	1.2	0.5	0.3	171.6	4.8	2.8	77.9	1.67
1460.0	79.7	2.1	0.8	0.5	0.3	83.4	3.7	4.5	67.5	1.57
1490.0	120.5	1.3	0.6	0.3	0.1	122.8	2.3	1.9	67.4	2.00
1500.0	108.9	2.2	0.9	0.4	0.2	112.6	3.7	3.3	87.4	1.67
1520.0	2315.8	3.9	1.5	0.8	0.4	2322.4	6.6	.3	24.0	2.12
1550.0	183.6	2.1	0.9	0.3	0.1	187.0	3.4	1.8	39.9	2.20
1580.0	290.4	0.9	0.4	0.2	<0.1	292.0	1.5	.5	10.9	bd1
1600.0	586.4	1.1	0.3	<0.1	<0.1	587.8	1.4	.2	3.1	bd1
1630.0	7.6	1.8	1.4	0.7	0.6	12.0	4.4	36.9	0.4	1.16
1640.0	10.4	1.8	1.7	0.9	1.0	15.8	5.4	33.9	0.5	0.96
1660.0	14.0	1.7	1.4	0.7	1.3	19.2	5.1	26.8	3.9	0.57
1670.0	8.7	2.8	3.5	1.6	1.4	17.9	9.3	51.6	2.9	1.16
1680.0	9.8	2.9	2.9	1.3	1.5	18.5	8.6	46.7	4.3	0.86
1690.0	7.9	2.4	2.5	1.2	1.4	15.4	7.4	48.5	4.3	0.84
1700.0	12.3	2.5	2.8	1.2	2.3	21.1	6.8	41.8	3.8	0.53
1710.0	17.9	4.2	4.3	1.8	3.3	31.5	13.6	43.1	9.7	0.55
1720.0	6.9	1.5	1.4	0.5	2.3	14.6	5.7	39.0	4.1	0.22
1730.0	11.4	1.5	1.3	0.5	1.0	15.8	4.4	27.7	1.7	0.51
1740.0	27.7	5.0	4.2	1.5	1.2	39.7	12.0	30.2	4.0	1.24
1750.0	23.4	4.4	2.1	1.2	1.2	32.3	8.9	27.6	5.2	1.05
1760.0	18.8	6.3	5.1	1.5	0.8	32.4	13.7	42.1	0.7	1.84
1770.0	20.7	9.7	11.0	3.9	2.2	47.4	26.8	56.4	5.4	1.81
1780.0	16.3	5.5	6.6	2.6	2.8	33.8	17.5	51.8	3.9	0.90
1790.0	17.1	2.9	2.2	0.8	5.4	28.4	11.3	39.8	6.2	0.15
1800.0	27.5	3.2	1.8	0.5	3.6	36.6	9.1	24.9	7.0	0.15
1810.0	27.9	3.6	2.2	0.9	3.1	37.7	9.8	25.9	7.3	0.27
1820.0	13.5	15.7	14.5	4.0	1.8	49.4	35.9	72.6	13.1	2.23
1830.0	43.7	11.9	9.9	2.9	1.7	70.1	26.4	37.6	6.9	1.09

N.B. 1. GAS CONCENTRATIONS EXPRESSED IN PPM (VOL. GAS/VOL. SEDIMENT)  
2. bd1 = BELOW DETECTION LIMIT

TABLE 1 (cont)

WELLNAME = BRIDGEWATER BAY #1

DATE OF JOB = JANUARY 1984

## HEADSPACE ANALYSIS DATA

DEPTH(m)	METHANE	ETHANE	PROPANE	ISOBUTANE	BUTANE	C1-C4	C2-C4	%WETNESS	C5-C7	i-C4/n-C4
1840.0	23.3	16.6	13.2	3.2	1.3	57.6	34.3	59.6	1.0	2.50
1850.0	9.3	15.4	10.9	2.4	1.2	39.1	29.8	76.2	1.4	2.02
1860.0	11.2	6.4	4.3	1.0	0.4	23.3	12.2	52.1	0.2	2.45
1870.0	15.4	13.0	9.8	2.8	1.3	42.2	26.9	63.6	2.4	2.10
1880.0	20.3	10.9	8.6	3.1	1.7	44.6	24.3	54.5	4.8	1.79
1890.0	13.1	10.1	7.3	2.6	1.2	34.5	21.4	61.9	1.8	2.16
1900.0	15.6	10.8	7.5	3.7	1.8	39.3	23.8	60.4	2.9	2.00
1910.0	23.5	10.0	7.8	3.6	2.3	47.1	23.6	50.1	6.7	1.57
1920.0	26.0	16.6	13.2	6.0	3.5	65.3	39.3	60.2	12.7	1.74
1930.0	26.8	7.3	4.6	2.2	1.0	41.9	15.1	36.0	3.0	2.21
1940.0	27.1	12.8	9.2	3.8	1.9	54.8	27.7	50.6	3.5	2.01
1950.0	12.5	3.9	1.8	0.6	0.2	18.9	6.5	34.2	0.4	2.42
1960.0	62.3	36.1	20.7	6.5	2.8	128.4	66.1	51.5	3.2	2.36
1970.0	56.6	41.5	22.9	7.5	3.6	132.1	75.4	57.1	5.5	2.10
1980.0	44.5	46.6	12.3	3.7	1.4	108.6	64.1	59.0	1.4	2.57
1990.0	29.8	12.9	7.5	2.7	1.2	54.2	24.3	44.9	1.5	2.20
2000.0	53.9	16.7	7.2	2.4	1.0	81.3	27.4	33.7	3.0	2.36
2010.0	49.1	14.1	6.6	2.6	1.3	73.6	24.5	33.3	5.0	2.05
2020.0	38.9	10.2	5.6	2.2	1.1	57.9	19.0	32.8	2.8	2.02
2030.0	51.4	12.4	6.8	2.8	1.2	74.6	23.2	31.1	3.0	2.31
2040.0	42.9	7.8	4.1	2.1	1.1	57.9	15.0	25.9	4.5	1.90
2050.0	40.0	10.1	6.4	2.6	1.3	60.4	20.4	33.7	3.0	2.11
2060.0	45.9	10.6	6.1	2.6	1.3	66.5	20.6	31.0	2.4	1.96
2070.0	45.7	9.2	5.3	2.3	1.5	64.1	18.5	28.8	1.6	1.54
2080.0	80.0	11.5	5.7	2.3	1.1	100.5	20.5	20.4	2.8	2.14
2090.0	81.9	15.5	7.9	2.8	1.4	109.5	27.6	25.3	3.2	1.97
2095.0	78.0	19.9	14.4	6.2	2.9	121.4	43.4	35.7	4.9	2.10
2120.0	18.9	4.4	2.9	1.6	0.9	28.7	9.8	34.1	3.4	1.72
2130.0	36.4	4.8	3.3	2.0	1.2	47.7	11.4	23.8	3.6	1.70
2140.0	50.0	5.3	3.2	2.0	1.3	61.8	11.8	19.1	3.4	1.57
2150.0	48.5	6.5	3.7	2.2	1.2	62.0	13.5	21.8	3.3	1.82
2160.0	11.9	2.5	1.4	0.6	0.4	16.8	4.9	29.0	5.0	1.36
2170.0	17.9	3.6	1.9	0.7	0.6	24.8	6.9	27.7	7.1	1.20
2180.0	64.3	7.5	5.4	3.7	1.4	82.3	18.0	21.9	2.6	2.76
2190.0	77.6	9.1	5.4	2.1	0.9	95.2	17.6	18.4	1.3	2.23
2200.0	75.1	8.6	4.9	2.0	0.9	91.4	16.3	17.9	1.5	2.15
2210.0	139.2	11.8	6.0	2.3	1.1	160.3	21.1	13.2	2.0	2.07
2220.0	65.3	7.2	4.4	2.1	1.3	80.2	14.9	18.6	2.1	1.68
2230.0	111.7	14.0	6.1	2.2	0.9	134.9	23.2	17.2	2.4	2.34
2240.0	279.3	36.5	15.8	4.7	2.3	338.6	59.3	17.5	4.2	2.09
2250.0	309.6	38.3	13.0	3.0	0.9	364.9	55.3	15.1	1.3	3.20
2260.0	427.1	45.7	17.3	3.5	1.2	494.9	67.8	13.7	2.0	2.90
2270.0	443.1	46.3	16.4	3.6	1.2	512.7	69.6	13.6	2.1	2.96
2280.0	423.9	38.9	15.8	3.0	0.9	482.5	58.6	12.1	1.2	3.23
2290.0	476.1	48.3	17.9	3.1	1.3	546.7	70.6	12.9	1.3	2.42
2300.0	695.7	52.4	17.8	2.9	1.0	769.7	74.1	9.6	1.2	2.99
2310.0	912.5	50.2	12.2	1.9	0.6	977.4	64.9	6.6	0.7	3.22
2320.0	453.7	44.2	14.0	2.4	0.9	515.3	61.5	11.9	1.3	2.63

N.B. 1. GAS CONCENTRATIONS EXPRESSED IN PPM (VOL. GAS/VOL. SEDIMENT)  
 2. bdl = BELOW DETECTION LIMIT

TABLE 1 (cont)

WELLNAME = BRIDGEWATER BAY #1

DATE OF JOB = JANUARY 1984

## HEADSPACE ANALYSIS DATA

DEPTH(m)	METHANE	ETHANE	PROPANE	ISOBUTANE	BUTANE	C1-C4	C2-C4	ZWETNESS	C5-C7	i-C4/n-C4
2330.0	583.6	62.6	16.8	2.6	0.9	666.5	82.9	12.4	1.1	2.73
2335.0	1516.8	208.4	97.4	15.9	6.7	1845.3	328.5	17.8	5.6	2.37
2350.0	490.0	84.9	23.5	3.6	1.2	603.2	113.2	18.8	1.6	2.88
2360.0	560.1	87.3	21.8	3.3	1.1	673.6	113.5	16.8	1.6	3.02
2370.0	643.3	126.4	39.6	6.5	2.2	818.2	174.8	21.4	2.7	2.95
2380.0	637.9	111.9	42.6	9.5	3.3	805.2	167.3	20.8	3.3	2.90
2390.0	1343.0	118.8	51.9	14.8	6.0	1534.6	191.6	12.5	5.9	2.45
2400.0	1731.8	191.5	76.6	20.3	7.5	2027.7	296.0	14.6	6.3	2.71
2410.0	1575.9	126.3	56.3	16.7	5.8	1781.1	205.1	11.5	4.8	2.88
2420.0	1037.7	151.6	73.1	20.0	6.7	1289.1	251.4	19.5	5.7	2.97
2430.0	546.4	111.9	54.0	13.5	4.6	730.3	183.9	25.2	5.3	2.92
2440.0	283.8	55.4	27.6	9.6	3.7	380.1	96.3	25.3	5.4	2.62
2450.0	263.1	52.4	25.9	10.0	3.8	355.2	92.1	25.9	4.9	2.64
2460.0	490.0	86.6	45.7	18.5	6.7	647.4	157.4	24.3	8.0	2.76
2470.0	118.1	24.7	25.6	13.8	6.0	188.2	70.2	37.3	12.4	2.30
2480.0	219.4	22.6	17.3	8.2	4.0	271.6	52.2	19.2	10.8	2.05
2490.0	673.5	97.5	63.9	27.1	11.5	873.5	200.0	22.9	25.1	2.35
2500.0	353.4	55.2	45.7	22.0	11.1	487.3	133.9	27.5	35.3	1.99
2510.0	552.2	86.3	71.9	21.7	25.0	757.2	205.0	27.1	34.7	0.87
2520.0	635.3	89.5	60.6	14.8	18.7	819.0	183.6	22.4	21.3	0.79
2530.0	477.5	61.3	36.0	6.7	6.9	588.3	110.8	18.8	2.9	0.96
2540.0	427.9	63.4	53.7	13.7	18.6	577.3	149.4	25.9	18.8	0.74
2550.0	610.9	77.6	65.9	15.0	26.6	796.0	185.1	23.3	26.5	0.56
2560.0	413.8	58.9	51.7	18.3	13.8	556.6	142.8	25.7	17.5	1.33
2570.0	649.7	62.9	49.2	18.4	9.4	789.7	139.9	17.7	12.8	1.96
2580.0	554.6	73.7	64.1	21.6	14.9	728.9	174.3	23.9	15.7	1.45
2590.0	801.9	117.3	107.7	32.5	29.0	1088.5	286.6	26.3	26.4	1.12
2600.0	868.6	120.8	96.7	29.9	23.8	1139.7	271.1	23.8	16.7	1.26
2610.0	1097.1	159.6	108.3	31.3	23.4	1419.7	322.6	22.7	15.2	1.34
2620.0	1122.0	152.8	95.1	25.8	21.5	1417.2	295.2	20.8	14.7	1.20
2630.0	837.0	101.3	78.0	26.1	20.0	1062.3	225.3	21.2	19.6	1.31
2640.0	492.1	74.6	39.0	18.8	14.3	638.9	146.8	23.0	18.3	1.31
2650.0	476.3	68.1	67.5	26.6	18.9	657.5	181.2	27.6	30.0	1.41
2660.0	203.6	27.0	30.6	13.3	9.6	284.1	80.5	28.3	19.9	1.38
2670.0	627.7	57.8	47.0	19.2	13.1	764.8	137.1	17.9	26.6	1.46
2680.0	1042.5	103.3	81.3	31.4	20.4	1278.9	236.4	18.5	35.2	1.54
2690.0	1842.1	382.5	469.0	191.0	148.9	3033.4	1191.3	39.3	275.6	1.28
2700.0	362.6	56.6	63.2	27.4	18.7	528.5	165.9	31.4	38.8	1.47
2710.0	1090.4	174.8	169.7	64.7	36.5	1536.2	445.8	29.0	52.9	1.77
2720.0	1339.7	195.6	149.2	53.0	28.3	1765.9	426.2	24.1	36.6	1.87
2730.0	759.1	126.8	100.0	36.7	21.3	1043.9	284.8	27.3	28.2	1.73
2740.0	1162.7	138.2	107.9	35.0	28.5	1472.3	309.6	21.0	32.7	1.23
2750.0	892.7	80.7	51.2	16.2	17.2	1058.0	165.3	15.6	17.4	0.94
2760.0	1437.9	149.6	118.6	35.9	53.6	1795.5	357.7	19.9	69.8	0.67
2770.0	1399.0	112.6	69.2	25.6	30.4	1636.8	237.8	14.5	39.5	0.84
2780.0	2239.1	177.5	103.9	36.0	25.5	2582.0	342.9	13.3	45.8	1.41
2790.0	1697.1	94.1	59.0	21.0	16.2	1867.3	190.2	10.1	29.1	1.30
2800.0	1349.2	87.2	64.8	25.7	17.1	1544.1	194.9	12.6	37.2	1.50

N.B. 1. GAS CONCENTRATIONS EXPRESSED IN PPM (VOL. GAS/VOL. SEDIMENT)  
 2. bdl = BELOW DETECTION LIMIT

TABLE 1 (cont)

WELLNAME = BRIDGEWATER BAY #1

DATE OF JOB = JANUARY 1984

## HEADSPACE ANALYSIS DATA

DEPTH(m)	METHANE	ETHANE	PROPANE	ISOBUTANE	BUTANE	C1-C4	C2-C4	ZWETNESS	C5-C7	i-C4/n-C4
2810.0	913.6	56.3	37.0	13.3	8.9	1029.1	115.4	11.2	19.6	1.50
2820.0	1314.2	87.9	62.8	20.9	18.7	1504.5	190.3	12.6	31.2	1.12
2890.0	1510.8	165.3	78.3	20.6	10.0	1785.0	274.2	15.4	6.1	2.07
2900.0	1852.2	231.8	113.5	28.4	14.9	2240.8	388.6	17.3	9.6	1.90
2910.0	875.6	127.5	77.7	21.5	15.4	1117.7	242.1	21.7	10.2	1.39
2920.0	1556.7	187.6	101.5	25.8	15.7	1887.3	330.6	17.5	10.0	1.64
2930.0	1856.5	234.5	132.3	32.2	26.1	2281.5	425.0	18.6	16.6	1.23
2940.0	1170.8	179.9	114.0	28.3	26.3	1519.3	348.5	22.9	17.9	1.08
2950.0	1168.3	191.1	116.8	21.2	20.1	1517.5	349.2	23.0	15.9	1.05
2960.0	1254.0	211.0	118.7	17.3	15.7	1616.7	362.7	22.4	14.2	1.10
2970.0	1183.6	129.6	62.7	8.7	8.2	1392.7	209.1	15.0	9.3	1.06
2980.0	1069.5	135.8	71.8	9.2	8.8	1295.2	225.7	17.4	7.4	1.05
2990.0	832.0	126.8	70.2	11.0	10.6	1050.6	218.6	20.8	8.0	1.03
3000.0	1296.2	214.4	110.9	16.7	15.6	1653.8	357.6	21.6	9.0	1.07
3010.0	1709.8	232.9	106.5	18.4	13.4	2081.0	371.2	17.8	7.0	1.38
3020.0	1574.7	191.9	93.9	20.3	13.5	1894.3	319.6	16.9	7.4	1.51
3030.0	1392.1	174.9	86.0	20.3	12.1	1685.4	293.3	17.4	7.9	1.68
3040.0	750.9	110.1	61.7	14.2	10.1	947.0	196.1	20.7	7.1	1.41
3050.0	919.1	143.5	78.5	16.8	12.6	1170.5	251.4	21.5	6.9	1.33
3060.0	847.7	90.6	43.1	9.7	6.5	997.6	149.9	15.0	3.3	1.51
3070.0	749.6	95.0	53.8	13.7	10.9	923.0	173.3	18.8	7.5	1.25
3080.0	987.6	101.0	48.2	10.8	8.5	1156.1	168.5	14.6	7.5	1.26
3090.0	1393.4	107.5	39.9	10.0	6.7	1557.5	164.1	10.5	5.2	1.50
3100.0	1222.9	116.9	59.1	16.8	10.9	1426.6	203.6	14.3	6.5	1.54
3110.0	1146.4	138.4	76.7	24.4	14.3	1402.2	255.8	18.2	9.2	1.71
3120.0	461.2	53.3	47.0	17.3	9.0	587.8	126.7	21.5	5.5	1.92
3130.0	568.3	74.9	55.3	19.2	10.9	728.6	160.3	22.0	7.3	1.77
3140.0	766.9	98.8	77.1	26.6	14.6	984.0	217.1	22.1	6.7	1.82
3150.0	707.9	92.2	71.9	26.0	12.4	910.4	202.5	22.2	9.2	2.09
3160.0	815.1	83.3	56.8	21.2	9.8	986.2	171.1	17.3	7.6	2.16
3170.0	868.0	110.3	98.4	35.7	20.5	1132.9	264.9	23.4	14.6	1.74
3180.0	801.9	85.4	76.5	28.5	15.1	1007.4	205.6	20.4	11.0	1.89
3190.0	813.8	109.9	105.4	41.9	22.6	1093.5	279.8	25.6	16.7	1.85
3200.0	998.9	126.5	150.3	60.5	34.8	1370.9	372.0	27.1	28.4	1.74
3210.0	1211.5	193.7	190.5	69.1	38.7	1703.6	492.0	28.9	28.4	1.78
3220.0	709.4	95.6	76.0	26.1	14.7	923.8	214.4	23.2	11.7	1.91
3230.0	897.9	112.9	86.4	31.6	16.4	1145.1	247.2	21.6	13.1	1.53
3240.0	887.0	111.0	76.2	27.2	14.1	1115.6	228.6	20.5	11.5	1.93
3250.0	577.4	94.2	74.1	26.2	13.3	785.1	207.7	26.5	9.5	1.97
3260.0	607.2	101.4	83.8	29.6	15.8	837.8	230.6	27.5	11.6	1.87
3270.0	507.0	86.6	75.9	29.2	15.7	714.4	207.3	29.0	12.1	1.85
3280.0	1211.4	167.3	124.0	40.4	21.5	1564.5	353.2	22.6	12.7	1.87
3290.0	1440.3	176.1	139.4	48.1	26.7	1630.7	390.4	21.3	19.0	1.80
3300.0	1435.2	219.3	212.7	73.9	45.9	1986.9	551.7	27.8	31.8	1.61
3310.0	1150.9	143.2	145.0	48.5	28.8	1516.4	365.5	24.1	19.0	1.69
3320.0	1266.4	150.5	138.4	42.2	24.2	1621.7	355.3	21.9	13.4	1.74
3330.0	1008.6	167.2	251.7	92.5	70.2	1590.2	581.6	36.6	48.0	1.32
3340.0	720.8	91.1	95.4	32.2	19.7	959.0	238.3	24.8	12.0	1.63

N.B. 1. GAS CONCENTRATIONS EXPRESSED IN PPM (VOL. GAS/VOL. SEDIMENT)  
 2. bdl = BELOW DETECTION LIMIT



TABLE 1 (cont)

WELLNAME = BRIDGEWATER BAY #1

DATE OF JOB = JANUARY 1984

## HEADSPACE ANALYSIS DATA

DEPTH(m)	METHANE	ETHANE	PROPANE	ISOBUTANE	BUTANE	C1-C4	C2-C4	%WETNESS	C5-C7	i-C4/n-C4
3350.0	654.8	88.0	103.1	35.3	21.8	902.9	248.2	27.5	13.2	1.62
3360.0	792.7	139.3	152.2	46.5	27.8	1158.4	365.7	31.6	16.5	1.67
3370.0	1265.4	229.5	205.2	53.6	30.1	1783.7	518.3	29.1	16.3	1.78
3380.0	768.4	110.4	99.2	29.9	17.1	1024.9	256.6	25.0	12.3	1.74
3390.0	1012.6	135.4	141.0	43.0	25.5	1357.5	344.9	25.4	18.3	1.69
3400.0	908.1	115.3	100.2	29.9	16.6	1170.1	262.0	22.4	11.3	1.80
3410.0	275.5	151.1	472.3	191.6	164.7	1255.3	979.8	78.1	142.0	1.16
3420.0	1563.1	264.2	168.4	31.0	18.1	2044.7	481.6	23.6	13.8	1.71
3430.0	1897.9	285.7	202.2	47.9	34.8	2468.6	570.7	23.1	26.4	1.37
3440.0	1655.6	240.5	172.0	38.9	26.9	2133.9	478.3	22.4	19.0	1.45
3450.0	100.0	18.6	15.6	3.6	2.6	140.4	40.4	28.8	1.8	1.42
3460.0	644.9	80.7	69.1	17.5	11.1	823.3	178.4	21.7	7.3	1.58
3470.0	1467.8	163.5	124.6	29.9	21.4	1807.2	339.4	18.8	16.9	1.40
3480.0	1852.8	250.5	188.2	39.4	30.9	2361.8	509.0	21.6	22.8	1.28
3490.0	1286.6	160.7	100.3	20.9	14.1	1582.6	296.0	18.7	10.9	1.48
3500.0	955.2	120.6	79.5	17.6	11.0	1183.9	228.7	19.3	7.9	1.59
3510.0	2317.0	341.1	241.9	47.6	39.1	2986.7	669.7	22.4	23.4	1.22
3520.0	1532.3	228.7	160.2	26.7	19.2	1967.1	434.8	22.1	14.5	1.39
3530.0	970.3	128.3	101.2	22.9	18.3	1241.1	270.7	21.8	13.8	1.25
3540.0	2462.8	342.2	226.0	39.7	32.7	3103.5	640.7	20.6	21.7	1.22
3560.0	571.0	5067.2	416.3	85.6	103.3	6243.4	5672.4	90.9	1368.5	0.83
3570.0	1092.4	209.1	208.4	33.9	45.9	1589.7	497.2	31.3	77.0	0.74
3580.0	899.1	217.3	333.7	62.6	83.3	1596.0	696.8	43.7	111.7	0.75
3590.0	366.1	46.6	87.2	15.2	17.3	532.4	166.3	31.2	32.5	0.88
3600.0	285.8	51.2	139.8	28.3	31.4	536.5	250.7	46.7	38.2	0.90
3610.0	188.7	21.3	47.4	8.0	10.2	275.7	87.0	31.5	33.8	0.78
3620.0	131.7	22.3	51.9	7.7	11.2	225.0	93.2	41.4	38.3	0.69
3630.0	228.2	30.4	43.8	6.2	8.6	317.2	89.0	28.1	36.8	0.72
3640.0	984.6	221.5	221.1	31.5	98.8	1557.5	572.9	36.8	108.4	0.32
3650.0	1066.6	211.6	259.5	47.9	105.3	1690.8	624.2	36.9	133.6	0.45
3660.0	823.3	175.5	196.5	34.9	81.6	1311.7	488.5	37.2	101.5	0.43
3670.0	1066.0	200.7	143.6	15.7	63.9	1489.9	423.9	28.5	132.9	0.25
3680.0	2636.4	570.6	485.2	71.9	257.3	4021.4	1385.1	34.4	342.1	0.28
3690.0	824.8	165.0	146.0	21.5	62.6	1219.9	395.1	32.4	69.9	0.34
3700.0	166.4	36.3	34.2	5.5	20.6	263.0	96.6	36.7	34.5	0.27
3710.0	1106.2	209.0	168.8	26.1	73.9	1584.0	477.8	30.2	75.9	0.35
3720.0	947.7	209.2	192.2	29.5	98.8	1477.4	529.7	35.9	144.7	0.30
3730.0	559.1	115.3	86.5	12.2	30.0	803.2	244.1	30.4	54.6	0.41
3740.0	1735.0	315.4	212.9	27.1	95.0	2385.3	650.3	27.3	94.3	0.28
3750.0	1130.5	140.0	92.9	14.1	33.8	1411.4	280.9	19.9	73.1	0.42
3760.0	621.0	74.2	61.2	10.5	22.0	789.0	168.0	21.3	46.7	0.48
3770.0	344.2	44.6	38.3	6.1	12.6	445.8	101.6	22.8	37.5	0.49
3780.0	650.8	89.1	68.7	11.6	30.5	850.8	200.0	23.5	55.6	0.38
3790.0	994.5	184.3	145.3	22.7	69.6	1416.4	421.9	29.8	101.6	0.33
3800.0	1066.4	197.7	144.7	19.7	56.6	1485.2	418.7	28.2	83.8	0.35
3810.0	907.7	146.3	114.5	18.7	44.8	1231.9	324.3	26.3	65.9	0.42
3820.0	1385.4	299.8	286.7	44.3	137.2	2153.5	768.1	35.7	167.9	0.32
3830.0	1492.3	308.5	230.1	35.9	106.0	2172.8	680.4	31.3	127.1	0.34

N.B. 1. GAS CONCENTRATIONS EXPRESSED IN PPM (VOL. GAS/VOL. SEDIMENT)  
 2. bdl = BELOW DETECTION LIMIT

TABLE 1 (cont)

WELLNAME = BRIDGEMATER BAY #1

DATE OF JOB = JANUARY 1984

## HEADSPACE ANALYSIS DATA

DEPTH(m)	METHANE	ETHANE	PROPANE	ISOBUTANE	BUTANE	C1-C4	C2-C4	ZMETNESS	C5-C7	i-C4/n-C4
3840.0	1825.0	339.3	217.1	26.8	89.8	2498.0	673.0	26.9	117.8	0.30
3850.0	1558.4	288.2	188.1	25.0	69.4	2129.2	570.8	26.8	88.0	0.36
3860.0	1087.0	215.2	149.2	18.7	69.9	1540.0	453.0	29.4	102.3	0.27
3870.0	1175.3	177.6	110.0	12.3	40.7	1516.0	340.7	22.5	51.0	0.30
3880.0	1586.9	320.0	221.2	27.3	92.9	2248.3	661.4	29.4	105.1	0.29
3890.0	1187.0	241.7	149.8	20.0	60.8	1659.4	472.4	28.5	61.2	0.33
3900.0	2484.0	498.6	321.1	40.5	153.1	3497.4	1013.3	29.0	171.5	0.26
3910.0	1514.6	280.6	185.2	23.9	80.2	2084.5	570.0	27.3	92.4	0.30
3920.0	888.7	150.5	99.8	14.1	40.6	1193.6	304.9	25.5	42.2	0.35
3930.0	1827.6	322.5	220.8	39.6	112.7	2523.3	695.6	27.6	148.1	0.35
3940.0	2722.0	409.3	235.7	32.9	93.0	3492.9	771.0	22.1	99.6	0.35
3950.0	2322.7	322.1	180.3	29.4	81.7	2936.2	613.6	20.9	97.6	0.36
3960.0	1560.2	225.1	147.0	26.0	74.5	2032.7	472.5	23.2	100.9	0.35
3970.0	1820.7	268.3	145.5	23.6	67.7	2325.8	505.1	21.7	87.0	0.35
3980.0	1738.9	236.3	113.5	15.8	47.5	2151.9	413.0	19.2	59.6	0.33
3990.0	1238.5	148.0	73.5	10.2	27.5	1497.7	259.2	17.3	33.3	0.37
4000.0	2031.3	254.5	111.0	14.3	43.9	2454.9	423.7	17.3	42.9	0.33
4010.0	2899.3	389.9	194.3	28.3	82.5	3594.2	654.9	19.3	86.9	0.34
4020.0	2856.8	296.7	152.0	21.8	65.3	3392.5	535.8	15.6	74.3	0.33
4030.0	939.9	77.8	59.0	10.1	23.7	1110.4	170.5	15.4	33.8	0.42
4040.0	529.1	46.2	37.0	6.7	16.7	635.6	106.5	16.8	30.0	0.40
4050.0	562.3	54.0	52.3	11.6	26.0	706.3	143.9	20.4	36.4	0.45
4060.0	3377.5	282.0	234.3	32.1	49.9	3975.8	598.3	15.0	63.0	0.64
4070.0	1844.7	196.6	152.7	21.4	43.0	2258.3	413.6	18.3	129.5	0.50
4080.0	1077.8	85.5	82.6	12.5	24.2	1282.5	204.7	16.0	32.4	0.51
4090.0	1773.0	140.6	138.5	21.7	41.8	2115.6	342.6	16.2	55.6	0.52
4100.0	407.3	76.1	113.8	21.1	38.5	656.8	249.5	38.0	42.1	0.55
4110.0	468.4	54.9	40.9	3.8	8.0	576.1	107.6	18.7	21.0	0.48
4120.0	258.2	54.3	59.4	7.3	14.8	394.0	135.8	34.5	29.6	0.50
4130.0	405.8	70.8	65.6	7.2	16.5	566.0	160.2	28.3	65.5	0.44
4140.0	550.8	93.0	91.7	8.4	16.6	760.5	209.7	27.6	23.0	0.51
4150.0	434.4	75.6	64.7	6.0	12.0	592.8	158.3	26.7	18.0	0.50
4160.0	240.8	37.7	33.9	3.9	8.6	324.9	84.1	25.9	20.6	0.46
4170.0	247.1	44.9	43.9	5.5	13.3	354.6	107.5	30.3	38.5	0.41
4180.0	197.3	31.6	33.4	4.5	9.5	276.4	79.1	28.6	21.0	0.48
4190.0	349.8	82.8	74.6	9.1	16.6	532.9	183.1	34.4	25.0	0.55
4200.0	478.9	58.5	52.9	6.0	13.0	609.3	130.4	21.4	31.5	0.46

N.B. 1. GAS CONCENTRATIONS EXPRESSED IN PPM (VOL. GAS/VOL. SEDIMENT)  
 2. bdl = BELOW DETECTION LIMIT

TABLE 2

## ROCK-EVAL PYROLYSIS DATA (two run)

WELLNAME = BRIDGEMATER BAY #1

DATE OF JOB = FEBRUARY 1984

DEPTH(m)	TMAX	S1	S2	S3	S1+S2	S2/S3	PI	PC	TDC	HI	OI
2700.0	421	0.66	1.76	1.23	2.42	1.43	0.27	0.20	1.18	149	104
2750.0	483	0.13	0.63	0.24	0.76	2.63	0.17	0.06	1.12	56	21
2800.0	530	0.13	0.67	0.27	0.80	2.48	0.16	0.07	0.94	71	28
2850.0	428	0.13	0.30	0.20	0.43	1.50	0.30	0.04	1.06	28	18
2900.0	501	0.17	1.46	0.64	1.63	2.28	0.10	0.14	1.31	111	48
2945.0	536	0.22	2.66	0.63	2.88	4.22	0.08	0.24	1.26	211	50
3000.0	502	0.21	1.03	0.62	1.24	1.66	0.17	0.10	1.36	75	45
3050.0	505	0.25	1.71	0.70	1.96	2.44	0.13	0.16	1.31	130	53
3100.0	474	0.21	0.86	0.46	1.07	1.87	0.20	0.09	1.26	68	36
3150.0	433	0.19	0.66	0.61	0.85	1.08	0.22	0.07	1.46	45	41
3200.0	508	0.26	1.39	0.86	1.65	1.62	0.16	0.14	1.19	116	72
3250.0	435	0.18	0.68	0.58	0.86	1.17	0.21	0.07	1.29	52	44
3300.0	436	0.30	1.06	0.57	1.36	1.86	0.22	0.11	2.93	36	19
3350.0	454	0.24	1.02	0.53	1.26	1.92	0.19	0.10	1.86	54	28
3400.0	435	0.25	0.68	0.44	0.93	1.55	0.27	0.08	1.19	57	36
3450.0	436	0.33	0.73	0.61	1.06	1.20	0.31	0.09	1.23	59	49
3500.0	428	0.30	0.38	0.35	0.68	1.09	0.44	0.06	0.88	43	39
3550.0	434	2.72	1.40	0.75	4.12	1.87	0.66	0.34	1.55	90	48
3600.0	429	2.64	8.58	1.58	11.22	5.43	0.24	0.93	3.57	240	44
3650.0	431	2.45	1.42	1.10	3.87	1.29	0.63	0.32	1.13	125	97
3700.0	427	0.63	0.71	0.59	1.34	1.20	0.47	0.11	0.97	73	60
3750.0	430	3.76	77.34	5.46	81.10	14.16	0.05	6.73	11.82	654	46
3800.0	429	1.60	21.86	2.50	23.46	8.74	0.07	1.95	4.22	518	59
3850.0	431	2.77	45.11	4.94	47.88	9.13	0.06	3.97	7.01	643	70
3900.0	432	0.69	1.82	0.67	2.51	2.72	0.27	0.21	1.24	146	54
3950.0	429	1.41	12.33	1.16	13.74	10.63	0.10	1.14	2.57	479	45
4000.0	429	0.94	5.40	1.06	6.34	5.09	0.15	0.53	1.73	312	61
4045.0	427	1.14	9.38	1.91	10.52	4.91	0.11	0.87	2.26	415	84
4100.0	428	3.13	21.08	3.00	24.21	7.03	0.13	2.01	4.78	441	62
4150.0	426	0.71	3.36	1.10	4.07	3.05	0.17	0.34	0.98	342	112
4200.0	431	3.82	51.60	5.14	55.42	10.04	0.07	4.60	9.55	540	53

TMAX = Max. temperature  
 S1+S2 = Potential yield  
 PC = Pyrolysable carbon  
 OI = Oxygen Index

S1 = Volatile hydrocarbons (HC)  
 S3 = Organic carbon dioxide  
 TOC = Total organic carbon  
 nd = no data

S2 = HC generating potential  
 PI = Production index  
 HI = Hydrogen index

## THEORY AND METHODS

July, 1983

This section details a series of geochemical methods which are commonly used in our laboratory, including those used to obtain the data presented in this report. Where applicable, the discussion is accompanied by a summary of the general theory used to interpret the data generated by each method.

### 1. SEDIMENTARY GAS ANALYSIS

#### a) Headspace Analysis

Headspace analysis is carried out using sealed containers (usually tinned cans) of wet cuttings. The containers are approximately three quarters filled with the cuttings and water to leave an appreciable headspace into which volatile hydrocarbons contained in the cuttings diffuse.

After covering about  $1\text{cm}^2$  of the container lid with liquid silicone and allowing the silicone to dry, the procedure involves placing a small hole in the lid through the silicone, then sampling an aliquot of the headspace gas with a gas injection syringe, and finally gas chromatographing this sample of gas under the following conditions: instrument = Shimadzu GC-8APF; column = 6' x 1/8" Chromosorb 102; column temperature =  $110^\circ\text{C}$ ; carrier gas = nitrogen at 23mls/min; injector temperature =  $120^\circ\text{C}$ ; detector temperature =  $120^\circ\text{C}$ ; analysis cycle =  $\text{C}_1\text{-C}_4$  components are flushed from the column in the forward direction and then the  $\text{C}_5\text{-C}_7$  compounds are removed from the column by backflushing.

The integrated areas of peaks representing each of the  $\text{C}_1\text{-C}_7$  components of the headspace gas are compared to the areas of the corresponding components of a standard gas of known composition. The calculated amount of each component in the sample gas is adjusted for the total headspace volume and reported as ppm (parts of gas per million parts of sediment by volume).

Data from headspace analysis is commonly used to identify the zone of oil generation by plotting gas wetness ( $\text{C}_2\text{-C}_4/\text{C}_1\text{-C}_4$ ) expressed as a % against sediment burial depth. Gas containing appreciable quantities of  $\text{C}_2\text{-C}_4$  components, termed wet gas (Fuex, 1977), is generally considered to be gas associated with oil generation. In addition, the ratio of isomeric butanes can sometimes be used for assessment of sediment maturity (Alexander et al., 1981). The amount of gas in sediments can be used to identify zones of significant gas generation and out-of-place gas (LeTran et al., 1975).

#### b) Cuttings Gas Analysis

This analysis is the same as Headspace Analysis with the exception that instead of analysing the gas in the container headspace, a known volume of the wet cuttings are transferred to the blender bowl of a Kenwood electronic blender with the lid modified to incorporate a septum, water at  $75^\circ\text{C}$  is added to leave a headspace of 160ml, and the mixture is blended at maximum speed for 2 minutes. Following a 2 minute settling period 1ml of the blending bowl headspace gas is analysed as described in section 1 a).

It is recommended that for the most meaningful gas data both headspace and cuttings gas analysis are carried out. In such cases we provide tabulations of the headspace, cuttings gas, and combined headspace/cuttings gas data. Normally, the combined data is used for plotting purposes.

### 2. SAMPLE PREPARATION

#### a) Cuttings

Cuttings samples are inspected by our qualified geological staff and then water washed according to the level of drilling mud and the lithology. In special cases (e.g. diesel contamination) it is necessary to lightly solvent wash samples. After washing, the samples are air dried, either sieved or picked free of cavings, and crushed to 0.1mm using a ring pulveriser.

#### b) Sidewall Cores

Sidewall samples are freed of mud cake and any other visible contaminants, and are also inspected for lithologic homogeneity. For homogeneous samples, the minimum amount of material required for the requested analyses is air dried and hand-crushed to 0.1mm. For non-homogeneous samples, the whole sample is air dried and handcrushed to 0.1mm.

#### c) Conventional Core and Outcrop Samples

These sample types are firstly inspected for visible contaminants, and where applicable, are freed of these contaminants to the best of our ability. Commonly, the surface of conventional core and outcrop samples are lightly solvent washed. The samples are then crushed to approximately 1/8" chips using a jaw crusher, air dried, and finally further crushed to 0.1mm using a ring pulveriser.

#### d) Petroleum/Aqueous Mixtures

The most common sample type in this category are RFT tests containing oil, water and mud. The mixture is placed in a separation funnel and allowed to stand for several hours which enables the petroleum and water/mud fractions to separate. The neat petroleum is isolated by removal of the lower layer (water/mud) from the funnel. To remove the last traces of water and mud, the neat petroleum is centrifuged at moderate speed.

When the volume of petroleum accounts for only a very small part of the sample the method above is unsatisfactory and the petroleum is solvent extracted from the mixture with dichloromethane. The petroleum is recovered by careful evaporation of the solvent from the organic layer.

### 3. TOTAL ORGANIC CARBON DETERMINATION

The total organic carbon value (TOC) is determined on the unextracted sediment sample. The value is determined by treating a known weight of sediment with hot dilute HCl for 1 hour to remove carbonate minerals, and then heating the residue to 1700°C (Leco Induction Furnace CS-044) in a atmosphere of pure oxygen. The carbon dioxide produced is transferred to an infra-red detector which has been calibrated with a series of standards, and the microprocessor of the Leco unit then automatically calculates the % TOC in the sample. To ensure reliable data a standard is run after every 10 samples, regular sample repeats are carried out, and at least one blank determination is carried out for each batch of samples.

The following scales are normally used for source rock classification based on % TOC data:

<u>Classification</u>	<u>Clastics</u>	<u>Carbonates</u>
Poor	0.00 - 0.50	0.00 - 0.25
Fair	0.50 - 1.00	0.25 - 0.50
Good	1.00 - 2.00	0.50 - 1.00
Very Good	2.00 - 4.00	1.00 - 2.00
Excellent	> 4.00	> 2.00

### 4. ROCK-EVAL PYROLYSIS

Although a preliminary source rock classification is made using TOC data a more accurate assessment accounting for organic source type and maturity is made by pyrolysis analysis. Two types of Rock-Eval pyrolysis services are offered: "one run" which involves pyrolysis of the crushed but otherwise untreated sediment and "two run" which involves pyrolysis of both the crushed, untreated sediment and sediment which has been rendered free of carbonate minerals by treatment with hot dilute HCl. The two run service offers considerably more reliable  $S_3$  data.

The method involves accurately weighing approximately 100mg of the sample into a sintered steel crucible and subjecting it to the following pyrolysis cycle:

- Stage (i) - Sample purged with helium for 3.5 minutes in unheated part of pyrolysis furnace;
- Stage (ii) - Sample heated at 300°C for 3 minutes to liberate free petroleum ( $S_1$  peak);
- Stage (iii) - Sample heated from 300°C to 550°C at 25°C/minute to produce petroleum from kerogen ( $S_2$  peak). The furnace is maintained at 550°C for one minute. Carbon dioxide produced during this pyrolysis up to 390°C in the case of "one run" and 550°C for "two run" is absorbed on a molecular sieve trap;
- Stage (iv) - During cool-down period the carbon dioxide produced during pyrolysis is measured ( $S_3$  peak).

The units used for Rock-Eval data are as follows:

$S_1, S_2, S_3$  = kg/tonne or mg/g of rock

$T_{max}$  = °C

Hydrogen Index =  $\frac{S_2}{TOC} \times \frac{100}{Y}$

Oxygen Index =  $\frac{S_3}{TOC} \times \frac{100}{Y}$

Rock-Eval data is most commonly used in the following manner:

- (i)  $S_1$  - indicates the level of oil and/or gas already generated by the sample according to the following scale:

<u><math>S_1</math> (mg/g or kg/tonne)</u>	<u>Classification</u>
0.00 - 0.20	Poor
0.20 - 0.40	Fair
0.40 - 0.80	Good
0.80 - 1.60	Very Good
> 1.60	Excellent

- (ii)  $S_1+S_2$  - referred to as the genetic potential this parameter is used for source rock classification according to the following criteria:

<u><math>S_1+S_2</math> (mg/g or kg/tonne)</u>	<u>Classification</u>
0.00 - 1.00	Poor
1.00 - 2.00	Marginal
2.00 - 6.00	Moderate
6.00 - 10.00	Good
10.00 - 20.00	Very Good

- (iii)  $S_1/(S_1+S_2)$  - this parameter is the production index (PI) which is a measure of the level of maturity of the sample. For oil prone sediments, values less than 0.1 are indicative of immaturity, the values increase from 0.1 to 0.4 over the oil window and values greater than 0.4 represent overmaturity. For gas prone sediments, the PI data shows a relatively smaller change with increasing maturity.
- (iv)  $T_{max}$  - the temperature corresponding to the  $S_2$  maxima. This temperature increases with increasingly mature sediments. Values less than 430°C are indicative of immaturity while values from 430/435 to 460°C represent the maturity range of the oil window.  $T_{max}$  values greater than 460°C are indicative of overmaturity.
- (v) HI, OI - the hydrogen ( $[S_2 \times 100]/TOC$ ) and oxygen ( $[S_3 \times 100]/TOC$ ) indices when plotted against one another provide information about the type of kerogen contained in the sample and the maturity of the sample. Both parameters decrease in value with increasing maturity. Samples with large HI and low OI are dominantly oil prone and conversely sample with low HI and large OI are at best gas prone.

#### 5. EXTRACTION OF SEDIMENT SAMPLES

Crushed sediment (maximum of 250g) and 300mls of purified dichloromethane are placed in a 500ml conical flask and are then blended for ten minutes with a Janke and Kunkel Ultra-Turrax T45/2G high efficiency disperser. After a ten minute settling period the solvent is separated from the sediment using a large Buchner filtration system. The extract is recovered by careful evaporation of the solvent on a steam bath and weighed. The weight of extract is used to calculate % EOM and ppm EOM using the following formulas:

$$\% \text{ EOM} = \frac{\text{Wt EOM (g)}}{\text{Wt Sediment Extracted (g)}} \times \frac{100}{1}$$

$$\text{ppm EOM} = \frac{\text{Wt EOM (mg)}}{\text{Wt Sediment Extracted (kg)}}$$

The following scale is used to classify the source rock richness of samples based on  $C_{12}^+$  extractables:

<u>Classification</u>	<u>ppm Total Extract</u>
Poor	0 - 500
Fair	500 - 1000
Good	1000 - 2000
Very Good	2000 - 4000
Excellent	> 4000

#### 6. SEPARATION OF PETROLEUM INTO CONSTITUENT FRACTIONS

Sediment extracts and crude oil or condensate samples are separated into saturate, aromatic and NSO (asphaltenes plus resins) fractions by medium pressure liquid chromatography (MPLC). That part of the petroleum which is soluble in pentane is applied to the MPLC system via a sample loop and is then pumped using pentane to a partially activated silicic acid pre-column which prevents further movement of the non-hydrocarbon compounds. The hydrocarbon components are pumped further to a Merck Si60 column where the saturate fraction is obtained by forward flushing and the aromatic fraction is recovered by reverse flushing. This separation procedure is monitored using a refractive index detector. To complete the separation the pre-column is removed from the MPLC system and flushed with dichloromethane: methanol (1:10). This non-hydrocarbon fraction is combined with the pentane insoluble material which is not applied to the MPLC system, and is labelled as the NSO fraction. The neat fractions are recovered by careful removal of the solvent by distillation and are weighed.

The weight of each fraction is used to calculate the % of each fraction in the petroleum and the ppm of each fraction in the sediment according to the following formulas:

$$\% \text{ Fraction} = \frac{\text{Wt Fraction}}{\text{Wt All Fractions}} \times \frac{100}{1}$$

$$\text{ppm Fraction} = \frac{\text{Wt Fraction (mg)}}{\text{Wt Sediment Extracted (kg)}}$$

The ppm hydrocarbon (saturates + aromatics) and ppm saturate values can be used to classify source rock richness and oil source potential respectively according to the following criteria:

<u>Classification</u>	<u>ppm Hydrocarbon</u>	<u>ppm Saturates</u>
Poor	0 - 300	0 - 200
Fair	300 - 600	200 - 400
Good	600 - 1200	400 - 800
Very Good	1200 - 2400	800 - 1600

The composition of the extracts can also provide information about their levels of maturity and/or source type (LeTran et. al., 1974; Philippi, 1974). Generally, marine extracts have relatively low concentrations of saturated and NSO compounds at low levels of maturity, but these concentrations increase with increased maturation. Terrestrially derived organic matter often has a low level of saturates and large amount of aromatic and NSO compounds irrespective of the level of maturity.

N.B. If requested by a client the NSO fraction is separated into asphaltenes and resins by conventional methods.

#### 7. EXTRACTABLE/TOTAL ORGANIC CARBON RATIOS

The ratios of EOM(mg)/TOC(g) and SAT(mg)/TOC(g) are determined from the appropriate data. The EOM (mg)/TOC(g) ratio can be used as a maturation indicator, especially if the parameter is plotted against depth for a given sedimentary sequence. In an absolute sense it is less reliable as a maturation indicator, although previous work (Tissot et. al., 1971; LeTran et. al., 1974) suggests that the following criteria can be used to determine maturity with this parameter:

<50	Low maturity
50-100	Moderate maturity
>100	High maturity

The ratios of EOM(mg)/TOC(g) and SAT(mg)/TOC(g) can be used collectively to provide information about source type. For example, if SOM(mg)/TOC(g) is >100, suggesting a high level of maturity, but the SAT(mg)/TOC(g) <20 it is very likely that the organic matter is gas prone. Conversely, the same EOM (mg)/TOC(g) value with a SAT(mg)/TOC(g) value >40 suggests oil prone source type.

#### 8. C<sub>12</sub><sup>+</sup> GAS CHROMATOGRAPHY

C<sub>12</sub><sup>+</sup> gas chromatography is commonly carried out on the saturate fraction but in certain instances is carried out on neat oil, condensate or extract. The analysis is carried out under the following conditions: instrument = Shimadzu GC-9A; column = 50m x 0.2mm ID OV101 vitreous silica; column temperature = programmed from 60°C to 280°C at 4°C/min; injection system = Grob splitless using a 30 sec. dump time and split ratio of 25:1; carrier gas = hydrogen at 2mls/min; injector temperature = 300°C; detector temperature = 310°C; recorder/integrator speed = 0.5cm/min; Sample = 1µl of 0.5% soln in pentane.

The following information is commonly obtained from C<sub>12</sub><sup>+</sup> gas chromatographic analysis:

(a) n-Alkane Distribution - The C<sub>12</sub>-C<sub>31</sub> n-alkane distribution is determined from the area under peaks representing each of these n-alkanes. This distribution can yield information about both the level of maturity and the source type (LeTran et. al., 1974).

(b) Carbon Preference Index - Two values are determined:

$$CPI(1) = \frac{(C_{23} + C_{25} + C_{27} + C_{29})Wt\% + (C_{25} + C_{27} + C_{29} + C_{31})Wt\%}{2 \times (C_{24} + C_{26} + C_{28} + C_{30})Wt\%}$$

$$CPI(2) = \frac{(C_{23} + C_{25} + C_{27})Wt\% + (C_{25} + C_{27} + C_{29})Wt\%}{2 \times (C_{24} + C_{26} + C_{28})Wt\%}$$

The CPI is believed to be a function of both the level of maturity (Cooper and Bray, 1963; Scalan and Smith, 1970) and the source type (Tissot and Welte, 1978). Marine extracts tend to have values close to 1 irrespective of maturity whereas values for terrestrial extracts decrease with maturity from values as high as 20 but don't usually reach a value of 1.

(c) C<sub>21</sub>+C<sub>22</sub>/C<sub>28</sub>+C<sub>29</sub> - This parameter provides information about the source of the organic matter (Philippi, 1974). Generally, a terrestrial source gives values <1.2 whereas a marine source results in values >1.5.

(d) Pristane/Phytane Ratio - This value was determined from the areas of peaks representing these compounds. The ratio renders information about the depositional environment according to the following scale (Powell and McKirdy, 1975):

<3.0	Relatively reducing depositional environment
3.0-4.5	Reducing/oxidizing depositional environment
>4.5	Relatively Oxidizing depositional environment

(e) Pristane/nC<sub>17</sub> Ratio - This ratio was determined from the areas of peaks representing these compounds. The value can provide information about both the depositional environment and the level of maturation (Lijmbach, 1975). Very immature crude oil has a pristane/n-C<sub>17</sub> ratio >1.0, irrespective of the depositional environment. However, the following classification can be applied to mature crude oil:

<0.5	Open water depositional environment
0.5-1.0	Mixed depositional environment
>1.0	Peat-swamp depositional environment

In the case of sediment extracts these values are significantly higher and the following classification is used:

- <1.0 Open water depositional environment
- 1.0-1.5 Mixed depositional environment
- >1.5 Peat-swamp depositional environment

(f) Phytane/ $n$ -C<sub>18</sub> Ratio - This ratio was determined from the areas of peaks representing these compounds. The value usually only provides information about the level of maturity of petroleum. The value decreases with increased maturation.

(g) Relative Amounts of  $n$ -Alkanes and Naphthenes - Since  $n$ -alkanes and naphthenes are the two dominant classes of compounds in the saturate fraction, a semi-quantitative estimate of the relative amounts of these compounds can be made from saturate GLC's. This information can be used to assess the degree of maturation and/or the source type of the petroleum (Philippi, 1974; Tissot and Welte, 1978). Very immature petroleum has only small proportions of  $n$ -alkanes, but as maturity increases the relative amount of  $n$ -alkanes increases. In addition, terrestrial petroleum has a greater proportion of high molecular weight naphthenes than marine petroleum.

#### 9. API/SPECIFIC GRAVITY

A specific gravity (SG) bottle was accurately weighed, then filled with crude oil at 60°F and finally reweighed. The weight difference was divided by the weight of an equal volume of water at 60°F to obtain the specific gravity. The following formula was then used to calculate the API gravity:

$$\text{API Gravity} = \left( \frac{141.5}{\text{SG}(60^\circ\text{F})} \right) - 131.5$$

The reported gravity value is the average of duplicate determinations.

#### 10. SULPHUR DETERMINATION

The % sulphur by weight is determined by dissolving 0.5g of the petroleum in 50mls kerosene and then analysing this mixture with an inductively coupled plasma (ICP) instrument which has been calibrated with a series of sulphur standards.

This parameter is influenced by the nature of the source material from which a crude is derived, the depositional environment of the source rocks, and reservoir alteration processes such as bacterial alteration.

#### 11. C<sub>1</sub>-C<sub>31</sub> WHOLE SAMPLE GAS CHROMATOGRAPHY

This method of analysis is normally only applied to oil or condensate samples. The technique provides a "picture" of the sample which shows good resolution of the low, medium and high molecular weight components. Whole sample GC data is considered to be more useful than C<sub>12</sub><sup>+</sup> saturate fraction GC data for oil or condensate samples.

The analysis is carried out under the same conditions as for the C<sub>12</sub><sup>+</sup> GC analysis with the following exceptions: column temperature = programmed from -20°C to 280°C at 4°C/min (uses cryogenic mode); injection is carried out in split mode; sample = 0.1µl of neat petroleum.

C<sub>1</sub>-C<sub>31</sub> analysis data can be used to obtain the same information as that obtained from C<sub>12</sub><sup>+</sup> GC but further provides detailed compositional data on the C<sub>1</sub>-C<sub>11</sub> fraction and enables calculation of the distillation range of the sample.

#### 12. MOLECULAR SIEVE EXTRACTION

This technique is used to isolate the branched/cyclic alkanes from the saturate fraction for gas chromatography/mass spectrometry analysis. A mixture of saturates: 5A molecular sieves: purified benzene in the proportions 1:5:12 by weight is placed in a 100ml round bottom flask and refluxed for 24 hours. After cooling, the sieves are filtered from the liquid phase and are washed with 4 x 10ml aliquots of benzene. The liquid phase plus washings are freed of benzene by distillation yielding the branched/cyclic compounds.

#### 13. COMPUTERIZED GAS CHROMATOGRAPHY/MASS SPECTROMETRY (GC/MS)

Gas chromatography/mass spectrometry employs a capillary column gas chromatograph linked in series with a mass spectrometer and data system (GC/MS/DS). As molecules are eluted from the capillary column they are bled into the analyser tube of the mass spectrometer where they are bombarded with high energy electrons and consequently fragment to form several ions each with molecular weights less than that of the parent molecule. The fragmentation pattern is characteristic of the particular molecular type. The spectrum of these ions (referred to as a mass spectrum) is recorded approximately once every second and all of the mass spectra recorded during a GC/MS/DS analysis are memorized by the data system. Since any given class of molecules will break down in the analyser tube to give one or more characteristic ion fragments of known molecular weight, after a GC/MS/DS analysis it is possible to examine the distribution of compounds within a given class by having the data system reproduce a mass fragmentogram (plot of ion concentration against gas chromatography retention time) representative of the particular class.



GC/MS/DS analyses can be carried out using one of the following two modes of operation:

- (i) Acquire mode - in which all ions in each mass spectrum are memorized by the data system;
- (ii) Selective Ion monitoring (SIM) mode - in which only selected ions of interest are memorized by the data system.

At present the sterane/triterpane fraction of petroleum is considered most useful for GC/MS/DS analysis and therefore we commonly use the second of the above mentioned modes of operation and run the following twenty ions which are pertinent to the sterane/triterpane fraction.

<u>Ion</u>	<u>Molecular Type</u>
177	Demethylated triterpanes
191	Normal triterpanes
205	Methyl triterpanes
163	Specific dehydroated triterpanes
356	Parent ion - C <sub>26</sub> triterpanes
370	Parent ion - C <sub>27</sub> triterpanes
384	Parent ion - C <sub>28</sub> triterpanes
398	Parent ion - C <sub>29</sub> triterpanes
412	Parent ion - C <sub>30</sub> triterpanes
426	Parent ion - C <sub>31</sub> triterpanes
183	Isoprenoids
217	Normal steranes
218	Normal steranes
231	4-methyl steranes
259	Diasteranes
358	Parent ion - C <sub>26</sub> steranes
372	Parent ion - C <sub>27</sub> steranes
386	Parent ion - C <sub>28</sub> steranes
400	Parent ion - C <sub>29</sub> steranes
414	Parent ion - C <sub>30</sub> steranes

GC/MS/DS analysis of the sterane/triterpane fraction can often provide information about the maturity and source type of petroleum and whether it has been affected by microorganisms. This technique is also often useful for oil:oil and oil:source rock correlation. The following sections indicate which parameters are used to obtain this information and summarize the theory behind their use.

#### Maturity

##### (i) Based on Steranes

- (a) The biologically produced  $\alpha\alpha\alpha(20R)$  stereoisomer is converted in sediments to a mixture of the  $\alpha\alpha\alpha(20R)$  and  $\alpha\alpha\alpha(20S)$  compounds. The ratio of  $C_{29} \frac{\alpha\alpha\alpha(20S)}{\alpha\alpha\alpha(20R) + \alpha\alpha\alpha(20S)}$  expressed as a percentage is about 25% at the onset of oil generation and increases almost linearly to a value of about 50% at the peak of oil generation.
- (b) The biologically produced  $\alpha\alpha\alpha$  steranes are partially converted during catagenesis to the corresponding  $\alpha\beta\beta$  series. The percentage of the C<sub>29</sub>  $\alpha\beta\beta$  component in the total C<sub>29</sub> steranes is another measure of maturation. The value of this parameter is about 25% at the onset of oil generation and it increases exponentially to a value of about 70% at the peak of oil generation.

##### (ii) Based on Triterpanes

- (a) The C<sub>31</sub>, C<sub>32</sub>, C<sub>33</sub>, C<sub>34</sub>, and C<sub>35</sub> hopanes have the biological R configuration at C<sub>22</sub>. On mild thermal maturation equilibration occurs to produce a 60/40 mixture of S/R. This equilibration occurs before the onset of oil generation.
- (b) The conversion of the biological 17 $\beta$ ,21 $\beta$  hopanes to the corresponding 17 $\alpha$ ,21 $\alpha$  and 17 $\beta$ ,21 $\alpha$  compounds is also maturation dependent. For C<sub>30</sub> triterpanes the ration of  $\frac{17\beta,21\alpha}{17\alpha,21\beta}$  decreases steadily from a value of about 0.4 at the onset of oil generation to a value of about 0.1 at peak oil generation.
- (c) Two of the C<sub>27</sub> triterpanes can also be used as maturity indicators. The ratio of 18 $\alpha$ (H) trisnorhopane to 17 $\alpha$ (H) trisnorhopane increases exponentially with increasing maturity from a value of approximately 0.2 at the onset of oil generation to approximately 1.0 at peak oil generation.
- (d) It is our experience that the ratio of the C<sub>27</sub> 18 $\alpha$ (H) + C<sub>27</sub> 17 $\alpha$ (H)

ratio decreases from values around 1.0 at the onset of oil generation to a value of approximately 0.4 at peak oil generation. With increasing maturity at levels greater than that equivalent to peak oil generation the ratio increases steadily to values greater than 3.0.

#### Source Type

##### (i) Based on Steranes

Algal organic matter contains steranes in which the C<sub>27</sub> compounds are more abundant than the C<sub>29</sub> compounds. General marine organic matter has approximately equivalent amounts of the C<sub>27</sub> and C<sub>29</sub> compounds while organic matter rich in land-plants usually has more of the C<sub>29</sub> steranes.

##### (ii) Based on Triterpanes

The triterpane components in petroleum can be derived from both bacteria and higher plants. The common bacterial products are the C<sub>27</sub>-C<sub>35</sub> hopanes and moretanes whereas the higher plant triterpanes are compounds other than hopanes or moretanes and are commonly C<sub>30</sub> compounds.

##### (iii) Based on Diasteranes

The diasteranes are not produced biologically but are formed during early diagenesis from sterane precursors. The diasterane ratios  $\frac{C_{27}(2OR)}{C_{29}(2OR)}$  and  $\frac{C_{27}(2OR+2OS)}{C_{29}(2OR+2OS)}$  should reflect the nature of the organic matter in the same manner as that outlined above for the steranes.

#### Biodegradation

It has been observed that in severely biodegraded petroleum the series of normal hopanes are converted to a series of A ring demethylated hopanes and the C<sub>29</sub> αα(2OR) sterane is selectively removed. For altered crudes which have not been degraded to this extent the severity of biodegradation can often be gauged by studying the isoprenoid and aromatic fractions. However, this type of investigation extends beyond a standard GC/MS/DS analysis.

#### Correlation

Our present approach to oil:oil or oil:source rock correlation problems is as follows:

- (i) Compare the distribution of compounds in the 177, 191, 217, 218, 259 and 400 mass fragmentograms for an oil or sediment extract to the distribution of compounds in the respective fragmentograms for the other oil(s) or sediment extract(s). It is necessary in this type of comparison to make allowance for small variations due to possible maturity differences.
- (ii) Examine the fragmentograms for peaks or sets of peaks which may represent compounds that are specific to the geological system under investigation. Normal steranes, diasteranes and bacterial hopanes cannot be used for this purpose because they are present in virtually all crude oils and sediment extracts. However, compounds like higher plant triterpanes, 4-methyl steranes, bisnor-hopane and botryococcane can often prove very useful for this purpose.

#### 14. CARBON ISOTOPE ANALYSIS

The measurement is carried out on one or more of the following mixtures; topped oil; saturate fraction; aromatic fraction; NSO fraction. The organic matter is combusted at 860°C in oxygen and the carbon dioxide formed is purified and transferred to an isotope mass spectrometer. The carbon isotope ratio is measured relative to a standard gas of known isotopic composition. In our case the standard gas is prepared from the NBS No. 22 oil. However, since the isotopic relationship between NBS No. 22 oil and the international reference PDB limestone are known, the values are adjusted to be relative to PDB limestone. Although carbon isotope data has been commonly used for oil to oil and oil to source rock correlation its most significant application is the identification of source of gas according to following criteria (Fuex, 1977):

$\delta^{13}C$ (PDB)	Gas Type
-85 + -58	Biogenic methane
-58 + -40	Wet gas/associated with oil
-40 + -25	Thermal methane

#### 15. VITRINITE REFLECTANCE MEASUREMENT

Vitrinite is a coal maceral which responds to increasing levels of thermal maturity. This response can be measured by the percent of light reflected off a polished surface of a vitrinite particle emersed in oil. Reflectance measurements are made on a number (40 if possible) of vitrinite particles in each sample, in order to establish a range and mean for reflectance values. Immature rocks have low reflectance values (0.2% Ro to 0.6% Ro), with mature values ranging from 0.6% Ro to 1.6% Ro. Very mature values are between 1.6% Ro and 2.4% Ro, while severely altered rocks have reflectances above 2.5% Ro.

Vitrinite reflectance results are best obtained from coals or rocks deposited in environments receiving large influxes of terrestrially-derived organic matter. Unfortunately, these environments are not conducive to the accumulation of large quantities of oil-prone organic matter. Also vitrinite reflectance cannot be performed on rocks older than Devonian Age, due to the absence of land plants in the older geologic time periods.

16. VISUAL KEROGEN

Visual kerogen assessment is carried out by the coal petrologist and/or the palynologist. In the case of the petrologist the assessment is made in reflected light using the plug prepared for vitrinite reflectance measurement, and reports the relative amounts of alginite, exinite, vitrinite and inertinite particles.

Visual study of kerogen by the palynologist is carried out in transmitted light and can indicate the relative abundance, size, and state of preservation of the various recognizable kerogen types and hence indicates the source character of a sedimentary rock. In addition, the color of the kerogen is related to the thermal maturity of the sediments and is often used as a maturation indicator.

The preparation of slides for visual kerogen assessment by the palynologist firstly involves concentration of the organic matter by removal of the rock matrix using hydrochloric and hydrofluoric acid treatment and heavy liquid separation. The organic concentrate is then mounted on a glass slide using Petropoxy.

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APPENDIX NO. 8

SOURCE ROCK POTENTIAL ANALYSIS OF THE

BRIDGEWATER BAY NO. 1 WELL

(PHILLIPS PETROLEUM COMPANY - CONFIDENTIAL)



January 4, 1984

INTER-OFFICE CORRESPONDENCE / SUBJECT:  
BARTLESVILLE, OKLAHOMA

Source Rock Potential Analysis  
of the Bridgewater Bay #1 Well,  
Otway Basin, Australia  
Charge No. RA4061  
EPS Report No. 2524L  
Copy 1 of 7 Copies

BVP-003-84

G. J. Koop  
Perth Office

Attn: N. C. Tallis

No significant liquid hydrocarbon source rock potential is indicated for the 13 sidewall cores (934 to 4175M) examined from the above cited well. Gas potential is indicated in the section (below approx. 3800 meters) that has Ro values higher than 1.0%. Seven of 13 samples are dominated by a liquid prone amorphous kerogen type, but the lack of fluorescence in the blue light range coupled with the low hydrogen index values (maximum of 135) indicate poor liquid potential. An oxidizing depositional environment probably lowered the kerogen's oil potential. An adjacent area with more reducing conditions could still be a candidate for a liquid hydrocarbon source rock.

Total organic carbon (TOC) values are "rich" in 9 out of 13 samples. The remaining TOC values are in the "fair" range for the 4 deepest samples collected between 3295 and 4175 M. This lower TOC zone unfortunately coincides with maturity levels that are optimum for liquid hydrocarbon generation or are approaching the thermal dry gas range.

The only missing parameter for a good liquid hydrocarbon source rock appears to be a more reducing, anoxic depositional environment, which could be nearby if paleogeography and paleocirculation patterns were favorable. Two references for pursuing this topic are: 1) Parrish, J. T. and Curtis, R. L., 1982. "Atmospheric circulation, upwelling, and organic rich rocks in the Mesozoic and Cenozoic eras." Palaeogeography, Palaeoclimatology, Palaeoecology, 40: pp. 31-66; and 2) Demaison, G. J. and Moore, G. R., August 1980, "Anoxic Environments and Oil Source Bed Genesis," AAPG Bulletin, V. 65-2, pp. 181-190.

A very high S1 pyrolysis peak in core 2733 meters may suggest an oil reservoir, migration pathway, or contamination. The production index (S1/(S1 + S2)) and the thermal extraction index (S1 x 100)/TOC generally indicate both increasing maturity and generation with

increasing depth. These data are consistent with the TAI (spore color) and Ro (vitrinite reflectance) maturity information. The hydrogen index values are low for all 13 samples. These figures again are consistent with the visual observations in which a combination of non-fluorescent, probably oxidized amorphous algal kerogen and land derived gas-prone kerogens indicates a low potential for liquid hydrocarbons.

Vitrinite quality in sample 4175 meters is poor and therefore the confidence in the data obtained is low.

Figures and Tables included in this report include:

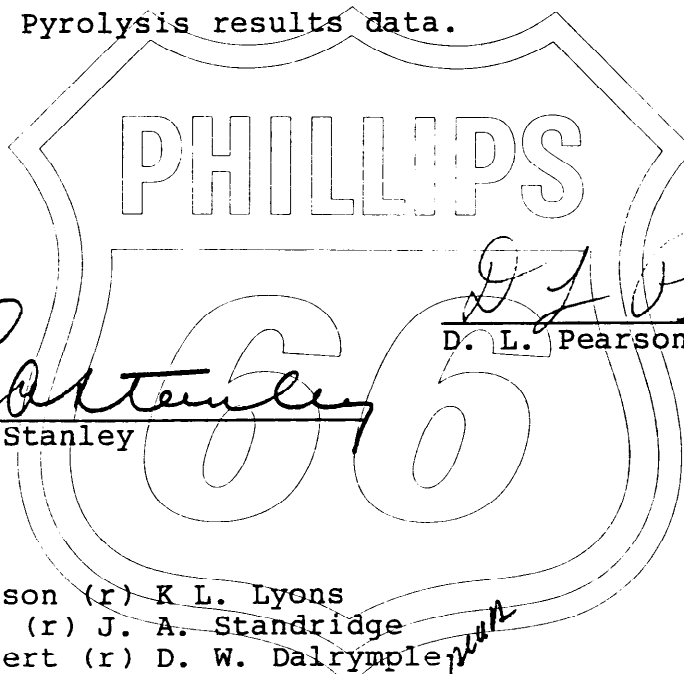
Figure 1. Thermal alteration and source rock potential plot.

Figure 2. Pyrolysis results plot.

Figure 3. Log % reflectance, unedited vitrinite data plot.

Table 1. Thermal alteration and source rock potential data.

Table 2. Pyrolysis results data.



Approved:

E. A. Stanley

D. L. Pearson

DLP/sjb

cc: W. E. Ryker  
 C. D. Davidson (r) K L. Lyons  
 J. C. Smith (r) J. A. Standridge  
 H. A. Kuehnert (r) D. W. Dalrymple

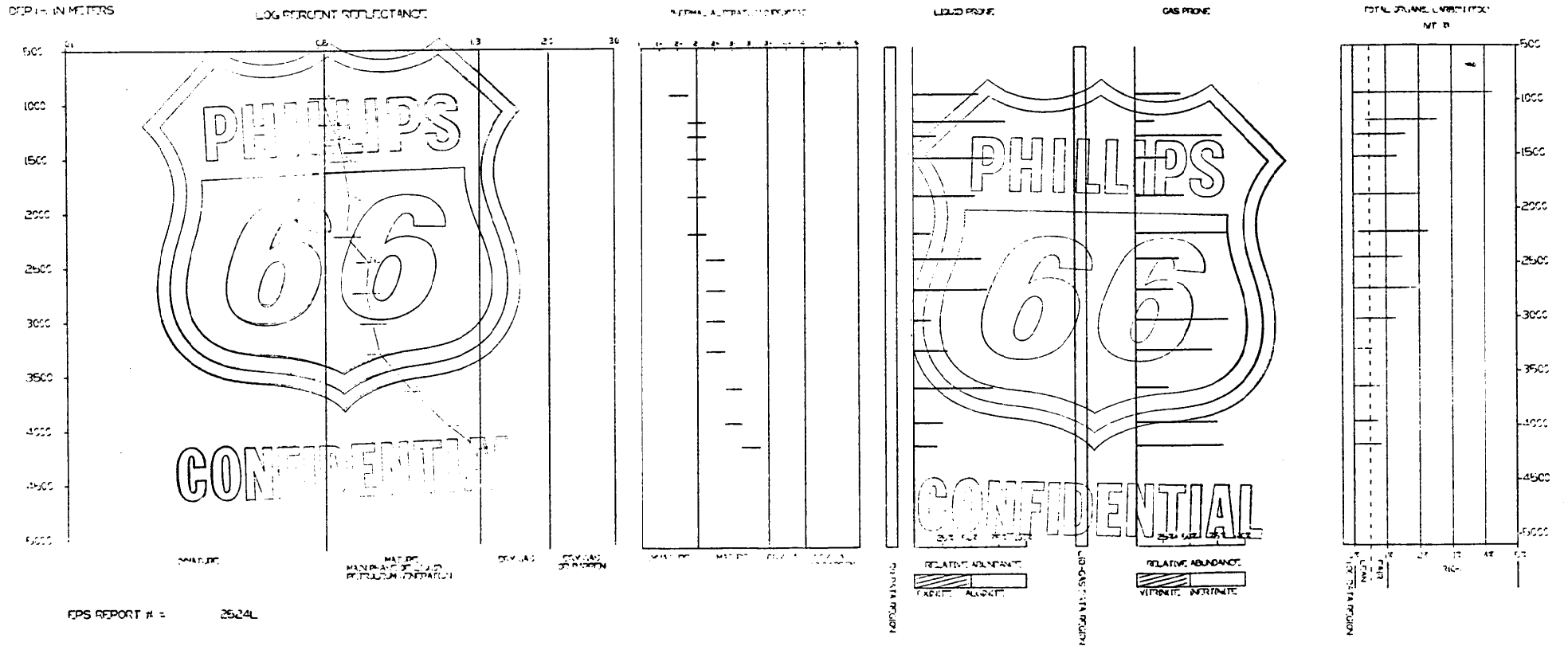
PE902248

This is an Enclosure indicator page.  
The enclosure PE902248 is enclosed within the container PE900161  
at this location in this document.

The enclosure PE902248 has the following characteristics:

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CONTAINER_BARCODE	= PE900161
NAME	= Bridgewater Bay 1 Figure 1 (Appendix 8) Thermal alteration And Source Rock Potential
BASIN	= OTWAY
TYPE	= WELL
SUBTYPE	= DIAGRAM
DESCRIPTION	= Bridgewater Bay 1 Figure 1 (Appendix 8) Thermal alteration And Source Rock Potential
W_NO	= W831
WELL_NAME	= BRIDGEWATER BAY-1
CLIENT_OP_CO	= PHILLIPS AUSTRALIAN OIL COMPANY





PE902249

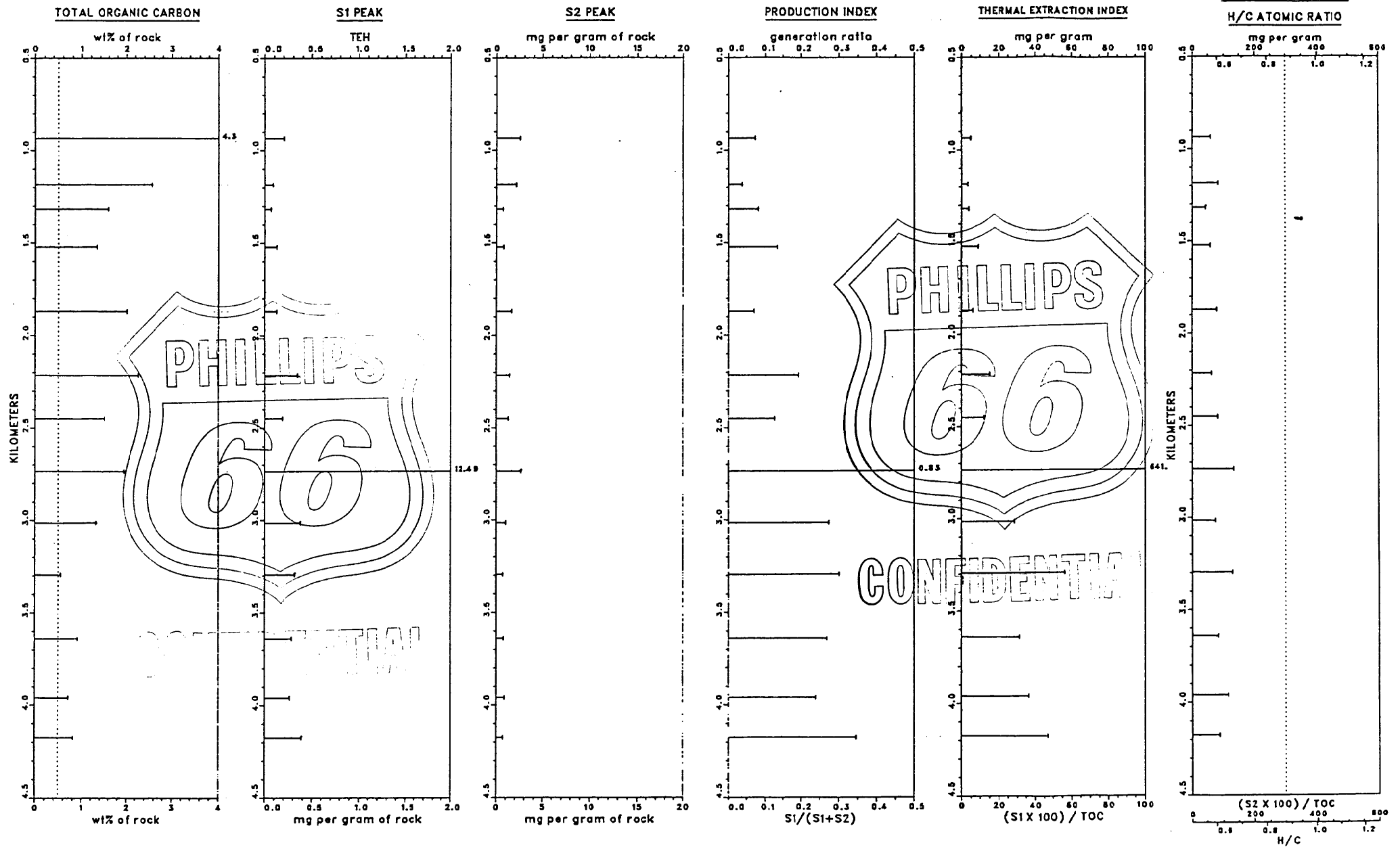
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The enclosure PE902249 is enclosed within the container PE900161  
at this location in this document.

The enclosure PE902249 has the following characteristics:

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CONTAINER_BARCODE	= PE900161
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BASIN	= OTWAY
TYPE	= WELL
SUBTYPE	= DIAGRAM
DESCRIPTION	= Bridgewater Bay 1 Figure 2 (Appendix 8) Pyrolysis Results
W_NO	= W831
WELL_NAME	= BRIDGEWATER BAY-1
CLIENT_OP_CO	= PHILLIPS AUSTRALIAN OIL COMPANY

PHILLIPS #1 BRIDGEWATER BAY, OTWAY BASIN, AUSTRALIA

PYROLYSIS RESULTS

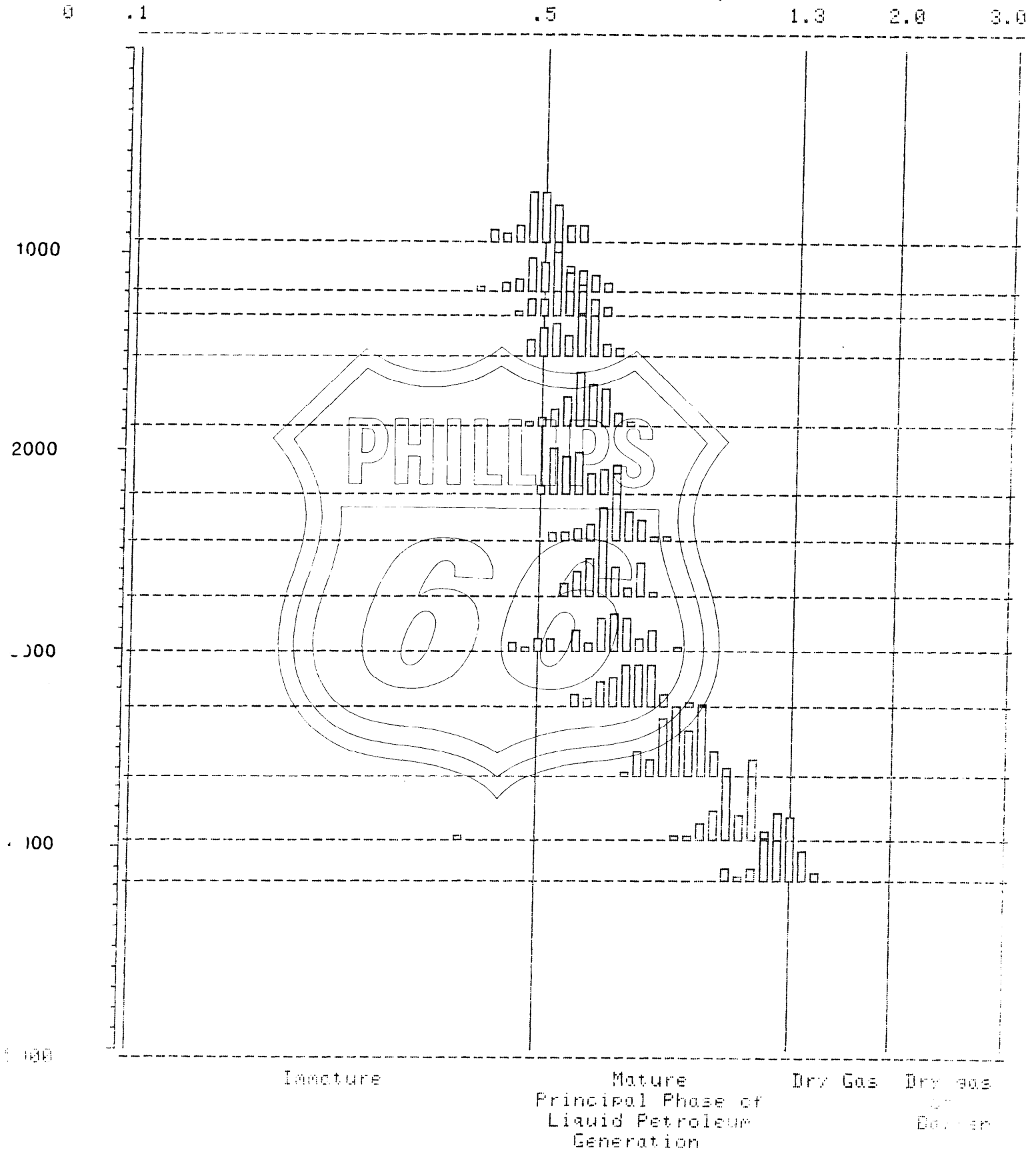


Log % Reflectance

EPS REPORT #2524L

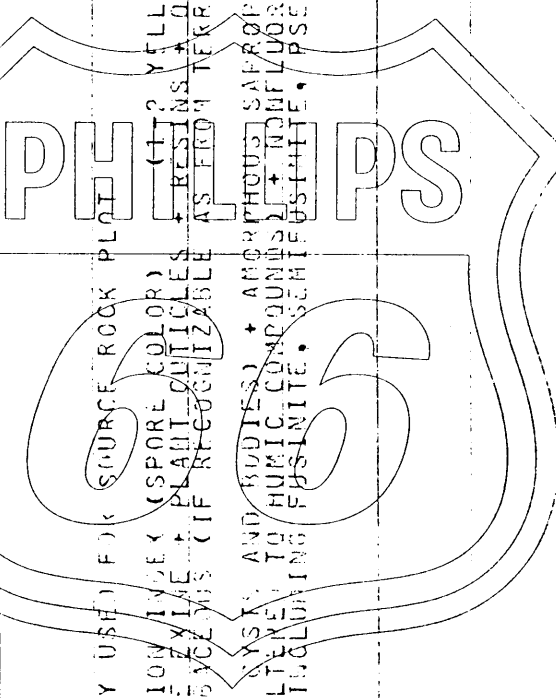
Unedited Vitrinite Data

METERS



NORMALIZED TO 100% BY VOLUME

INTERVAL (METERS)	BASE	TYPE	TAI	HITE	ALITE	VITITE	NITE	INITE	RO MEAN	STND. DEV.	MODE	LOW	HIGH	NO. OF VIT. READINGS	TOTAL ORGANIC CARBON (WT %)
934	934	SW	2	3	5	40	2	2	0.49	0.04	0.50	0.40	0.57	50	4.26
1185	1185	SW	2	2	8	15	3	3	0.52	0.05	0.52	0.42	0.62	48	2.56
1318	1318	SW	2	10	1	35	4	4	0.54	0.04	0.54	0.45	0.63	50	1.59
1522	1522	SW	2	5	9	15	1	1	0.56	0.05	0.56	0.46	0.66	50	1.33
1870	1870	SW	2	3	3	20	3	3	0.57	0.05	0.55	0.47	0.69	50	2.01
2215	2215	SW	2	5	1	30	5	5	0.57	0.05	0.52	0.50	0.67	50	2.27
2450	2450	SW	2	5	1	20	2	2	0.65	0.05	0.67	0.52	0.74	48	1.50
2735	2735	SW	2	5	6	15	2	2	0.64	0.06	0.63	0.54	0.77	50	1.95
3015	3015	SW	2	8	1	17	7	7	0.67	0.06	0.64	0.57	0.77	40	1.31
3295	3295	SW	2	10	2	30	4	4	0.70	0.06	0.66	0.58	0.82	51	1.55
3640	3640	SW	3	5	2	15	1	1	0.86	0.07	0.87	0.71	1.00	77	0.90
3960	3960	SW	3	5	2	30	4	4	1.07	0.07	1.12	0.92	1.20	57	0.71
4175	4175	SW	3	5	1	40	4	4	1.29	0.06	1.24	1.16	1.40	52	0.81



TERMINOLOGY USED FOR SOURCE ROCK PLOT

TAI = THERMAL ALTERATION INDEX (SPORE COLOR) (1-2 YELLOW) (3-4 BROWN) (5-6 DARK BROWN) (5 BLACK)  
 INITE = FOLIOLAR AND SPHERE-LIKE PLANT CUTICLES + RESINS + OTHER STRONGLY FLUORESCENT ORGANIC MATERIALS  
 + AMORPHOUS HERCYNOLITE (IF RECOGNIZABLE AS FROM TERRESTRIAL SOURCE - IF NOT IT IS RECORDED  
 AS ALGALITE)  
 ALGALITE = ALGAL DEBRIS + AMORPHOUS SAFFROL  
 ALGALITE = WOODY TISSUE (ALTERED TO HUMIC COMPOUNDS) + NON-FLUORESCENT TRANSLUCENT MATERIAL  
 + AMORPHOUS HERCYNOLITE + SEMI-CRYSTALLINE PSEUDOCRYSTALLINE, MACRINITE, & INERTODERIVATIVE  
 + RATIO = ECM / (1.29 \* IHC)

PYROLYSIS RESULTS FOR SAMPLES FROM THE PHILLIPS #1 BRIDGEWATER BAY, OTWAY BASIN, AUSTRALIA TABLE 2

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STRAT. INTERVAL	SPL TYP	SAMPLE DEPTH METERS	TOTAL ORGANIC CARBON WT.%	S1 MG.HC/G.ROCK	S2 MG.HC/G.ROCK	PRODUCTION INDEX S1/(S1+S2)	THERMAL EXTRACTION INDEX MG/G.	HYDRROGEN INDEX MG/G.	HYDRROGEN TO CARBON ATOMIC RATIO	GEOCHEM SAMPLE CODE
	SWC	934.0	4.26	.20	2.57	.072	4.69	60.3	.576	EP83GCD
	SWC	1184.0	2.56	.08	2.14	.036	3.12	83.6	.605	EP83GCE
	SWC	1318.0	1.59	.06	.69	.081	3.77	42.8	.554	EP83GCC
	SWC	1522.0	1.33	.12	.77	.135	9.02	57.9	.573	EP83GCCG
	SWC	1870.0	2.01	.12	1.61	.069	5.97	80.1	.601	EP83GCCH
	SWC	2215.0	2.50	.34	1.42	.193	14.98	62.6	.579	EP83GCCJ
	SWC	2450.0	1.50	.18	1.24	.127	12.00	82.7	.604	EP83GCCK
	SWC	2735.0	1.51	12.49	2.63	.826	640.51	134.9	.670	EP83GCCM
	SWC	3015.0	1.55	.37	.98	.274	28.24	174.8	.594	EP83GCCN
	SWC	3295.0	.90	.31	.72	.307	56.36	130.9	.665	EP83GCCO
	SWC	3640.0	.71	.28	.83	.269	31.11	84.4	.606	EP83GCCP
	SWC	3960.0	.81	.38	.72	.239	36.62	116.9	.647	EP83GCCQ
	SWC	4175.0	.81	.38	.72	.345	46.91	.88.9	.612	EP83GCCR

